MONTANA-DAKOTA
UTILITIES CO.
A Division of MDU Resources Group, Inc.

400 North Fourth Street
Bismarck, ND 58501
(701) 222-7900

March 21, 2018

Executive Secretary
ND Public Service Commission
State Capitol Building
Bismarck, ND 58505

Re: Case No. PU-15-592
Post Construction Monitoring

Montana-Dakota Utilities Co. (Montana-Dakota), a Division of MDU Resources Group, Inc., herewith submits the Post-Construction Bird and Bat Fatality Monitoring Report for the Thunder Spirit Wind Energy Facility (TSWEF) located in Adams County, North Dakota.

While the primary objective of this one-year post-construction assessment was to evaluate impacts to eagles, the study also evaluated the overall level of bird and bat mortality attributable to collisions with wind turbines for the entire facility on an annual basis and evaluated if the estimated impacts were lower, similar, or higher than other reported regional and national estimates.

No eagle fatalities were found during the one year of survey.

The estimated overall bird fatality rate of 1.49 birds/MW/year was within the low end of the range of other wind energy facilities in the Midwest (0.27 fatalities to 8.25 birds/MW/year). The raptor fatality estimate at the TSWEF (0.18 raptors/MW/year) was within the range and similar to the raptor fatality rates (zero to 0.47 raptors/MW/year) observed in the Midwest. The estimated bat fatality rate at TSWEF of 12.72 bats/MW/year was within the overall range observed at other Midwest sites (0.16 to 30.61 bats/MW/year).

Given the primary focus being on eagles and other raptors, surveys at TSWEF were conducted every other week. This sampling plan was designed based on carcass persistence times for large birds (e.g., eagles) and not for bats. Carcasses or species groups with shorter persistence times should be surveyed on a shorter time period to achieve a more confident fatality rate estimate. The shorter persistence time, as well as a lower searcher efficiency rate compared to larger birds (i.e., bats are harder to find than large birds), results in the very low probability of a bat being available and detected. The low average probability of carcasses being available and detected result in very high inflation factors for bat carcasses found.

To gain a better understanding of the overall level of bat mortality attributable to collisions with wind turbines at TSWEF, Montana-Dakota plans to conduct additional bat fatality monitoring in 2019, once Phase II of TSWEF is completed and operational. The Phase II Post-Construction Bat Fatality Monitoring Report will be submitted to the Commission when those efforts are completed.

Please contact me at 701-222-7856 or at tamie.aberle@mdu.com with additional questions or follow up as necessary.

Please acknowledge receipt by stamping or initialing the duplicate copy of this letter, attached hereto, and returning the same in the enclosed self-addressed, stamped envelope.

Sincerely,

Tamie A. Aberle
Director of Regulatory Affairs

Cc: Andy McDonald
Abbie Krebsbach
Alan Welte

Post-Construction Bird and Bat Fatality Monitoring for the Thunder Spirit Wind Energy Facility Adams County, North Dakota

Final Fatality Report

Prepared for:

Thunder Spirit Wind, LLC

400 North 4th Street
Bismarck, North Dakota 58501

Prepared by:

Clayton Derby, Derek Klostermeier, Ray Tupling, and Katherine Moratz

Western EcoSystems Technology, Inc.
4007 State Street, Suite 109
Bismarck, North Dakota 58503

March 1, 2018

EXECUTIVE SUMMARY

Thunder Spirit, LLC, a subsidiary of Montana-Dakota Utilities Co., has developed the Thunder Spirit Wind Energy Facility (TSWEF or Project) in Adams County, North Dakota. The TSWEF is comprised of 43 2.5-megawatt turbines, for a total nameplate capacity of 107.5 megawatts. Western EcoSystems Technology, Inc. was contracted to conduct surveys, following the Bird and Bat Conservation Strategy, for the purpose of estimating the direct impacts of the wind energy facility on bird and bats, with a focus on documenting any impacts to eagles. Further, estimated impacts were evaluated to determine if they were lower than, higher than, or similar to, other reported regional and national estimates.

While the primary objective of the study was to evaluate any impacts to eagles, the study was to also evaluate the overall level of bird and bat mortality attributable to collisions with Project turbines on an annual basis. The fatality monitoring study consisted of four components: 1) standardized carcass surveys of selected turbines, 2) searcher efficiency, 3) carcass persistence trials, and 4) adjusted fatality estimates for birds and bats. Ten of the 43 turbines (approximately 23%) were selected as full plot searches, while the remaining 33 turbines were road and turbine pad searches such that all turbines were searched. Searches were conducted approximately twice a month from April 5, 2016 to February 1, 2017.

During the study, 30 birds representing 18 species and 25 bats representing four species were found. The most commonly found bird species were mallard, ring-necked pheasant, and Swainson's hawk. No eagles were found. Hoary bat accounted for the majority of the bat fatalities found. Bird fatalities were found throughout the spring, summer, and fall, while bat fatalities were found predominantly during the fall season.

Combining all seasons and search plot types, the overall estimated fatality rate for small birds within the TSWEF was 2.0 birds/turbine/year or 0.8 birds/megawatts/year. The annual fatality estimate for large birds within the TSWEF was 1.72 birds/turbine/year or 0.69 birds/megawatts/year. The annual fatality estimate for raptors was 0.45 birds/turbine/year or 0.18 birds/megawatts/year. The annual bat fatality estimate was 31.8 bats/turbine/year or 12.72 bats/megawatts/year.

As no eagles were found, no estimate for eagle impacts was calculated. The annual overall bird fatality estimate for the TSWEF was relatively low compared to other wind energy facilities in the Midwest. While within the overall range of reported bat fatality rates, the bat fatality estimate was relatively high when compared to other Midwest wind energy projects. These estimates could be higher due to several factors including number of carcasses found, short persistence time in the field of trial carcasses, and long search interval designed to focus on general impacts and not specifically bats.

STUDY PARTICIPANTS

Western EcoSystems Technology

Derek Klostermeier	Project Manager
Clayton Derby	Senior Manager
Carmen Boyd	Data Manager
Ray Tupling	Statistician
Andrew Telander	Statistician
Ann Dahl	GIS Technician
Katherine Moratz	Report Compiler
Wendy Bruso	Technical Editing Manager
Katie Michaels	Technical Editing Coordinator
Dave Klein	Technical Editor
Karen Seginak	Field Technician
Katherine Moratz	Field Technician
Dawn Hagerman	Field Technician

REPORT REFERENCE

Derby, C., D. Klostermeier, R. Tupling, and K. Moratz. 2018. Post-Construction Studies for the Thunder Spirit Wind Energy Facility, Adams County, North Dakota. Final Fatality Report: April 2016 – February 2017. Prepared for Thunder Spirit, LLC, Bismarck, North Dakota. Prepared by Western EcoSystems Technology, Inc., Bismarck, North Dakota. March 1, 2018.

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INTRODUCTION

Thunder Spirit, LLC (Thunder Spirit), a subsidiary of Montana-Dakota Utility Co., has developed the Thunder Spirit Wind Energy Facility (TSWEF or Project), located in Adams County, North Dakota (Figure 1). Thunder Spirit contracted Western EcoSystems Technology, Inc. (WEST) to develop and implement a standardized study post-construction fatality monitoring survey, following the Project's Bird and Bat Conservation Strategy, to estimate the direct impacts of the wind energy facility on birds and bats, with a focus on documenting any impacts to eagles. This protocol for the post-construction monitoring is similar to protocols used at other wind energy facilities across the nation and follows guidance for post-construction monitoring described in the US Fish and Wildlife Service (USFWS) *Land-Based Wind Energy Guidelines* (USFWS 2012). This report presents the results of standardized avian and bat fatality surveys within the Project area.

While the primary objective of the study was to evaluate any impacts to eagles, the study was to also evaluate the overall level of bird and bat mortality attributable to collisions with wind turbines for the entire facility on an annual basis and evaluate if the estimated impacts were lower, similar, or higher than other reported regional and national estimates. The methods for the fatality study consist of four primary components: 1) standardized carcass surveys of selected turbines as well as road and pads throughout the facility, 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers, 3) carcass persistence trials to estimate the length of time that a carcass remains in the field for possible detection, and 4) analysis of estimated bird and bat fatalities using appropriate statistical analysis. In addition to site-specific data, this report compares TSWEF results to results of studies conducted at other wind energy facilities across North America and in the Midwest region.

STUDY AREA

The Project is located in Adams County, North Dakota, approximately five miles (mi; eight kilometers [km]) northeast of Hettinger, North Dakota. The topography is rolling to flat with several low buttes and ridges. The area is a mix of grassland (some native) and cultivated cropland (mainly corn [*Zea mays*] and spring wheat [*Triticum aestivum*]), with areas of wetlands (mainly freshwater ponds and ponds), shrubs and trees, and rural homes (USFWS National Welands Inventory [NWI] 2017, US Department of Agriculture Croplands Data Layer [CDL] 2016). Most of the historic short-grass prairie has been converted to crop production or is used for livestock grazing. Currently, the site consists of 43 Nordex wind turbine generators, each 2.5-megawatt (MW) capacity (Dvorark 2014), with 80-meter (m; 262.5 feet [ft]) steel tubular towers and 100-m (328.1 ft) diameter rotors (Figure 1).

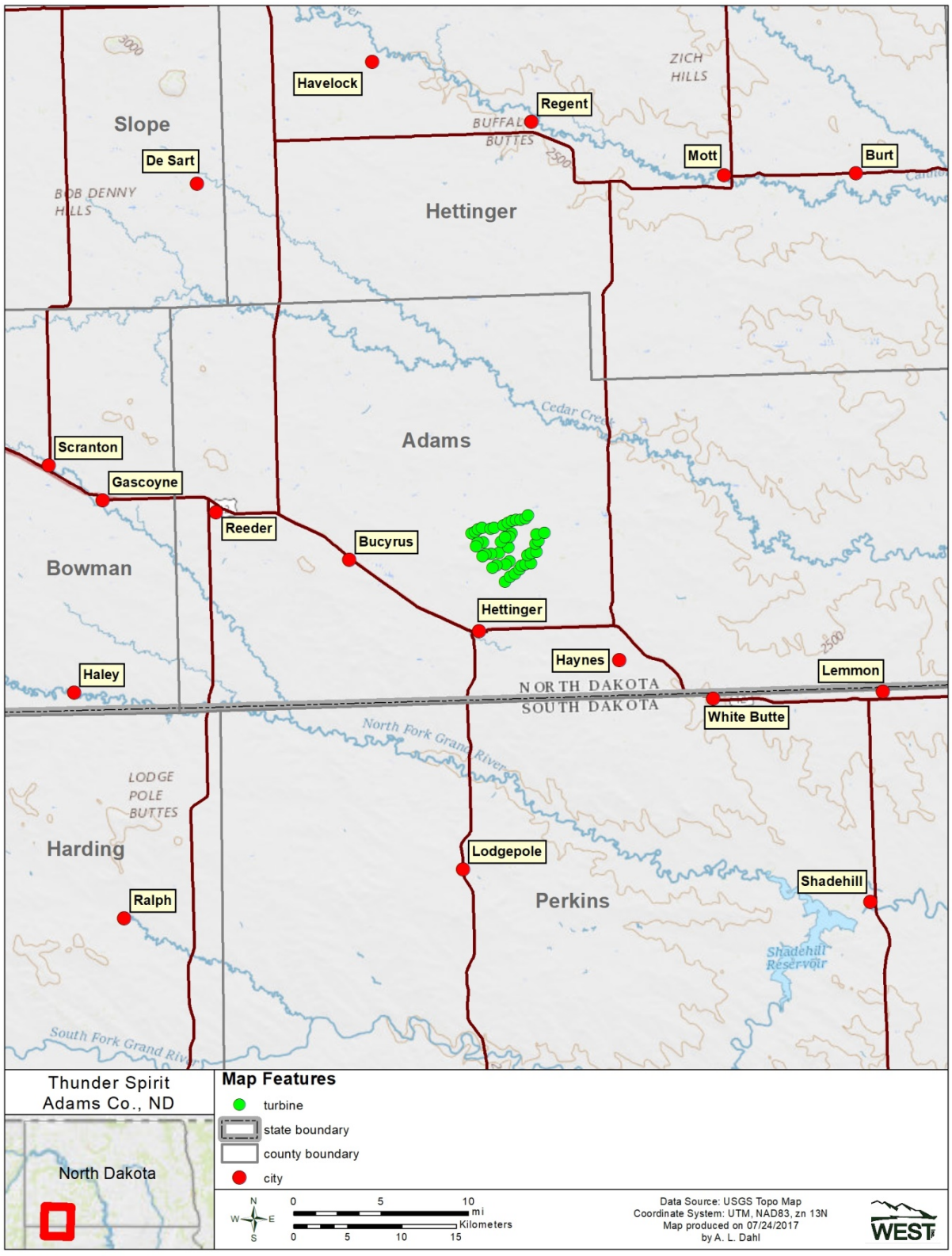

Figure 1. Location of the Thunder Spirit Wind Energy Facility, Adams County, North Dakota.

METHODS

Avian and Bat Fatality Surveys

The study used four primary components to estimate annual mortality: 1) standardized carcass surveys of selected turbines as well as road and pads throughout the facility, 2) searcher efficiency trials, 3) carcass persistence trials, and 4) analysis of estimated bird and bat fatalities using appropriate statistical analysis.

Standardized Carcass Searches

The objective of standardized carcass searches was to estimate bird and bat mortality at TSWEF. Standardized carcass searches were scheduled to begin in early April, 2016 and end February 1, 2017. Seasons were defined as follows: spring (March 16 to May 15), summer (May 16 to August 15), fall (August 16 to October 31), and winter (November 1 to March 15).

Ten of the 43 turbines (approximately 23%) were selected as full plot searches centered on the turbine, while the remaining 33 turbines were road and turbine pad searches. Each survey plot was to be searched two times per month. All plots were searched before scheduled carcass searches to clear all search plots of previous mortalities.

Turbines were selected for sampling using a systematic design with a random start and adjusted, if necessary, to ensure search effort was spread throughout the facility (Figure 2). Roads and pads were searched up to 80 m (262 ft) from turbines, and full search plots were 160 m by 160 m (525 ft by 525 ft) centered on each turbine. Plots were searched by searchers walking transects spaced 10 m (33 ft) apart; searchers scanned the ground up to five m (16 ft) away from the transect.

All bird and bat casualties located within the search plots were recorded and cause of death determined, if possible. For carcasses where the cause of death was not apparent, the assumption that the fatality was a wind turbine collision fatality was made. Any injured bird or bat observed in the search plots was recorded and treated as a fatality for the purposes of analyses. All carcasses were given a unique identification code and data recorded included species, sex and age when possible, date and time collected, location, condition (i.e., intact, scavenged, feather spot), and any comments that indicated possible cause of death. Bat carcasses were collected, but bird carcasses were left in the field; bird carcasses were spray-painted to identify them as previously recorded. Data for all fatalities found outside of the search areas by searchers were recorded following the above methods. All fatalities found in non-search areas (outside the search plots or road and pad search areas) were classified as incidental discoveries and were documented similarly as carcasses found during standard searches.

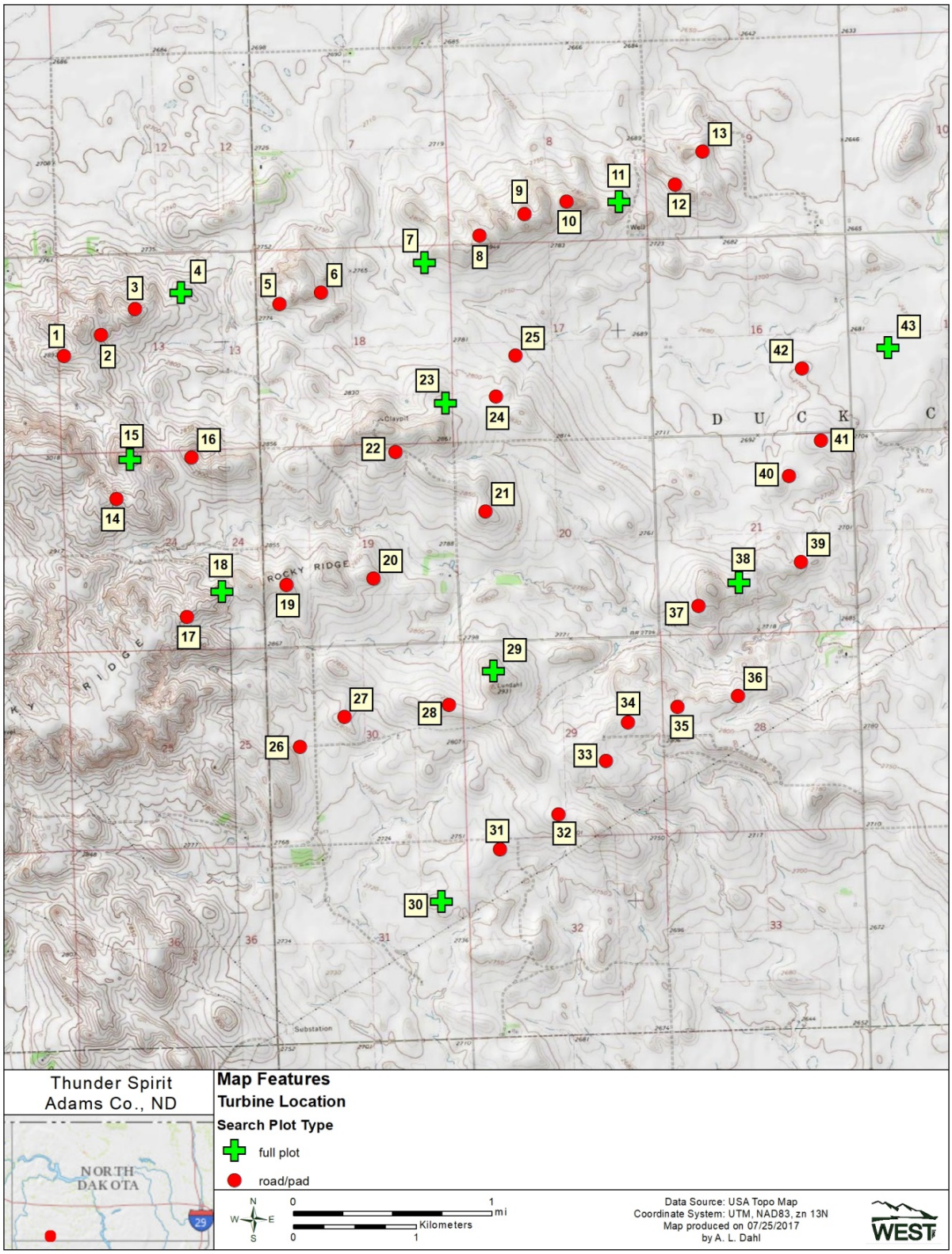

Figure 2. Location of search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Searcher Efficiency Trials

The objective of searcher efficiency trials was to estimate the percentage of bird and bat casualties found by searchers. Searcher efficiency trials occurred in some search plots (full and road/pad) and during each season. Searcher efficiency was estimated by the size of bird carcass (large or small birds or bat), season (spring, summer, fall, and winter), and plot search type (full plot and road/pad). Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by searchers, thereby correcting for detection bias.

The person placing the carcasses did not inform the searcher conducting the searches when the trial was being conducted or where trial carcasses were placed. Carcasses used for searcher efficiency trials were primarily non-native/non-protected or commercially available species (rock pigeon [*Columba livia*] and ring-necked pheasant [*Phasianus colchicus*] for large birds, house sparrow [*Passer domesticus*] and juvenile Japanese quail [*Coturnix japonica*] for small birds, and house mouse [*Mus musculus*] to represent bats if no bats were available).

All searcher efficiency trial carcasses were placed at random locations within the search plot, including both full plots and road and pad search areas, prior to that day's scheduled survey. Carcasses were placed in representative vegetation and visibility conditions so that searcher efficiency could be measured for easy, moderate, and difficult visibility conditions. Each trial carcass was discreetly marked with electrical tape so that it could be identified as a study carcass after it was found. The number and location of the searcher efficiency carcasses found during the carcass survey 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 (measured in days) a carcass persisted in the search plot before being removed by scavengers or by other means. The carcass persistence estimate predicted how many fatalities were removed before carcasses were found during scheduled carcass searches. Possible means of carcass removal included removal by predator, scavenger, insects, or agricultural practices, such as being plowed into a field. Estimates of carcass persistence were used to adjust fatality estimates.

Persistence trial birds were placed randomly within road and pad search areas or full search plots. Carcass persistence trials were conducted throughout the year to incorporate the effects of varying weather, climatic conditions, and scavenger densities. Carcass species composition was similar to that used for searcher efficiency trials. Trial carcasses were placed in representative areas of vegetation and visibility conditions. Persistence trial carcasses were marked with electrical tape for recognition by searchers and other personnel.

Field personnel monitored carcass persistence trials for 21 days. Trial carcasses were checked every day for the first four days, and then on day seven, day 10, day 14, and day 21. This

schedule varied somewhat depending on weather and coordination with the other survey work. At the end of the 21-day period, any remaining evidence of the carcass was removed.

Statistical Analysis

All fatalities found outside search plots were excluded from statistical analysis. Any fatalities found during clearing searches were also excluded from analysis.

Fatality Rate Estimation

To determine the rate at which birds and bat fatalities occurred, the number of carcasses found in each search plot was tallied; however, carcasses can persist for variable amounts of time and can be detected with varying levels of success based on carcass characteristics and ground cover. In addition, a portion of the search plot may not be searchable, due to vegetation cover or topography. To account for these variables, statistical analyses were developed to adjust the observed count of carcasses based on the project-specific rate of carcass persistence, the ability of searchers to detect carcasses, and the proportion of carcasses likely to have fallen in searched areas.

Estimates of facility-related fatalities were based on:

(1) Observed number of carcasses found during standardized searches during the monitoring year for which the cause of death was either unknown or attributed to the facility;

(2) Carcass persistence rates, which incorporates search frequency, expressed as the estimated average probability a carcass was expected to remain in the study area and be available for detection during carcass persistence trials;

(3) Searcher efficiency, expressed as the proportion of placed carcasses found by searchers during searcher efficiency trials; and

(4) Search area adjustment based on the plot size and carcass density (the distribution of carcass distance from the turbine within a search plot).

Fatality estimates were calculated for the following groups: 1) bats, 2) all birds, 3) small birds, 4) large birds, and 5) raptors. Overall and seasonal fatality estimates were calculated and included a 90% confidence interval. Fatality estimates were calculated using the Huso estimator (Huso 2010; Huso US Geological Service [USGS] Guide 2012).

Definition of Variables

The following variables are used in the equations below for the Huso estimator (Huso 2010; Huso USGS Guide 2012):

c_i total number of carcasses in category i (e.g., combinations of size, visibility, season, search interval)

n	number of turbines sampled at the Project
k	number of carcass categories
$\hat{a}_i$	density-weighted area correction for category *i*
I_i	time interval between the previous search and discovery for category *i*
$\hat{\bar{I}}_i$	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 is both available to be found during a search and is found, as determined by the persistence trials and the searcher efficiency trials
$\widehat{F}_i$	per turbine mortality for category *i*
$\hat{m}$	total per turbine mortality

Estimation of Carcass Persistence Rates

To estimate fatality rates, analysis must also account for how long carcasses persist, otherwise known as removal bias. Removal bias estimates how likely a carcass persisted in the search plot given the search interval. Estimates of carcass persistence rates are used to adjust carcass counts (the number of fatalities used in analysis). Carcass persistence can be modeled as a function of a variety of variables including ground visibility, size, season, and the interactions between these variables. The average probability of persistence of a carcass, $\widehat{r}_i$, is estimated from an interval censored carcass persistence model. Exponential, log-logistic, lognormal, and Weibull distributions are fit and the best model is selected using an information theoretic approach known as AICc, or corrected Akaike Information Criteria (Burnham and Anderson 2002).

Estimation of Searcher Efficiency Rates

Searcher efficiency rates, $\hat{p}_i$, are estimated using a logistic regression. Potential covariates for this logistic model include ground visibility, season, size (i.e., large or small bird), plot search type (e.g., full plot or road/pad) and interactions between these variables. The logistic regression models 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 is selected using AICc. Area Correction

The area correction for the estimate was 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 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 GIS), 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. The density distribution of carcasses is 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. Truncation bounds for the density distributions are set at 0 meters (carcasses cannot be negative distance from turbines) and at the maximum search radius from the turbine (to account for carcasses that may fall beyond the plot boundary). Fits are obtained using a weighted maximum likelihood approach (Khokan et al 2013), where the weight for each observed carcass distance is the inverse of the fraction of area searched at the distance where the carcass was found, multiplied by the inverse of the probability of detection ($\hat{\pi}$) for that carcass. Weighted maximum likelihood accounts for carcass detection probabilities that vary systematically with distance from turbines. When not enough carcasses were found, a triangular distribution was used for the distance density distribution, where the max distance comes from Hull and Muir (2010).

Adjusted Facility-Related Fatality Rates

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

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

where $\hat{v}_i$ = min(1, $\hat{\hat{I}}_i / I_i$). The model assumes that searchers have a single opportunity to find each carcass, even though some carcasses may persist through multiple searches before being detected. Therefore, a carcass is included in adjusted fatality estimates if it has been available since the last search, and no longer. The probable time since death, recorded in the field, is 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* is given by

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

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

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

The per-turbine fatality estimates, standard errors, and 90% confidence intervals were calculated using bootstrapping (Manly 1997). A total of 1,000 bootstrap samples were used. The

standard deviation of the bootstrap estimates is the estimated standard error. The lower 5th and upper 95th percentiles of the 1,000 bootstrap samples were estimates of the lower limit and upper limit of 90% confidence intervals.

RESULTS

Avian and Bat Fatality Surveys

Ten full plot and 33 road and pad areas (Figure 2) were searched within the TSWEF over the course of the fatality monitoring study for a total of 813 turbine searches. Thirty birds and 25 bats were found during standardized carcass surveys or incidentally (Table 1). A full listing and description of fatalities is presented in Appendix A. Turbine searches concluded in late March. However, due to extreme winter weather and poor road conditions, there was a period of almost two months between searches in late March and the previous searches in late January/early February. This was deemed too long for an appropriate search interval, so the late March surveys were excluded from analysis, but any carcasses found would be included in Table 1. Therefore, data in this report used to determine the estimated fatality rates for birds and bats are from the interval April 5, 2016 to February 1, 2017. Additionally, there was an extended period from early December to late January were full access and surveys were not possible given road and weather conditions but surveys continued at accessible turbines and these data are included in the analysis. No fatalities were found during any winter searches so the missed searches in winter had no effect on our annual estimates and only influenced the calculated search interval.

Search Plots

The shape of the road and pad search plots was digitized based on recent aerial imagery; shape and size varied primarily due to differences in shape and size of turbine pads and location of access roads. The percentage of the total road and pad area searched decreased with distance from the turbine due to the constraints of the irregular search plots and limited search area in most cases (Table 2).

Bird Fatalities

During the study, 24 bird fatalities were found during scheduled searches and inside of search plots (excluding clearing search; Table 1 and Figure 3). These 24 birds were used in developing the estimated fatality rate for birds. Fatalities included 15 species, one unidentified blackbird, and one unidentified sparrow. Four additional bird fatalities, representing four species, were found incidentally outside of search plots. Two fatalities, representing two species, were found during clearing searches. The most common bird species found overall were mallard (*Anas platyrhynchos*; three carcasses; 10.0%), ring-necked pheasant (three carcasses; 10.0%), sharp-tailed grouse (*Tympanuchus phasianellus*; three carcasses; 10.0%), Swainson's hawk (*Buteo swainsoni*; three carcasses; 10.0% of bird fatalities), and house sparrow (two carcasses; 6.7%). All other bird fatalities represented single carcasses (3.3%) of individual species or unidentified species. Five raptors were found during the study: three Swainson's hawks and one

northern harrier (*Circus cyaneus*) found during scheduled surveys, and one unidentified hawk found incidentally off plot (Table 1). No eagle fatalities were found during surveys.

The most bird fatalities (excluding clearing search carcasses and off plot casualties) found at any one search plot was two fatalities at three turbines (turbines 18, 23, and 38; Figures 3 and 4). No spatial patterns in bird fatality locations were evident. Bird fatalities, excluding clearing search carcasses, were recorded up to 80 m (262.5 ft) from search turbines. Seventy-five percent of fatalities were found within 50 m (164 ft) of the search turbine (Table 3 and Figure 5). Bird fatalities, excluding clearing search carcasses, peaked in the fall search season; fewer carcasses were observed in spring and summer and no bird carcasses were found during the winter (Figure 6).

Table 1. Bird and bat casualties (number of individuals and percent composition), including casualties found during the clearing search, recorded during post-construction monitoring at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 4, 2016 to February 1, 2017.

	Casualties During Scheduled Searches		Clearing Search Casualties		Casualties Off Plot		Total	
Species	**Total**	**% Comp.**	**Total**	**% Comp.**	**Total**	**% Comp.**	**Total**	**% Comp.**
Birds								
mallard	3	12.5	0	0	0	0	3	10.0
Swainson's hawk	3	12.5	0	0	0	0	3	10.0
house sparrow	2	8.3	0	0	0	0	2	6.7
ring-necked pheasant	2	8.3	0	0	1	25.0	3	10.0
sharp-tailed grouse	2	8.3	1	50.0	0	0	3	10.0
blue-winged teal	1	4.2	0	0	0	0	1	3.3
brown thrasher	1	4.2	0	0	0	0	1	3.3
dark-eyed junco	1	4.2	0	0	0	0	1	3.3
gray partridge	1	4.2	0	0	0	0	1	3.3
horned lark	1	4.2	0	0	0	0	1	3.3
mourning dove	1	4.2	0	0	0	0	1	3.3
northern flicker	1	4.2	0	0	0	0	1	3.3
northern harrier	1	4.2	0	0	0	0	1	3.3
spotted towhee	1	4.2	0	0	0	0	1	3.3
unidentified blackbird	1	4.2	0	0	0	0	1	3.3
unidentified sparrow	1	4.2	0	0	0	0	1	3.3
yellow warbler	1	4.2	0	0	0	0	1	3.3
European starling	0	0	1	50.0	0	0	1	3.3
unidentified hawk	0	0	0	0	1	25.0	1	3.3
western meadowlark	0	0	0	0	1	25.0	1	3.3
yellow-rumped warbler	0	0	0	0	1	25.0	1	3.3
Overall Birds[1]	**24**	**100**	**2**	**100**	**4**	**100**	**30**	**100**
Bats								
hoary bat	18	78.3	0	0	0	0	18	72.0
eastern red bat	2	8.7	0	0	1	50.0	3	12.0
little brown bat	1	4.3	0	0	1	50.0	2	8.0
silver-haired bat	1	4.3	0	0	0	0	1	4.0
unidentified bat	1	4.3	0	0	0	0	1	4.0
Overall Bats[1]	**23**	**100**	**0**	**0**	**2**	**100**	**25**	**100**

[1] Sums of values may not add to total value shown, due to rounding.

Table 2. Proportion of road and pad plots searched within the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Distance from Turbine (meters)	Area Searched (square meters)	Total Area (square meters)	% of Area Searched
10	314.15	314.15	1.00
20	637.35	942.48	0.39
30	806.17	1,570.80	0.11
40	973.21	2,199.11	0.08
50	1,135.56	2,827.43	0.06
60	1,293.10	3,455.75	0.05
70	1,448.43	4,084.07	0.04
80	1,753.56	4,712.39	0.03

Table 3. Distribution of distances from turbines of bird and bat casualties found during scheduled carcass searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

Distance to Turbine (meters)	% Bird Casualties	% Bat Casualties
0 to 10	29.2	26.1
10 to 20	12.5	13.0
20 to 30	8.3	30.4
30 to 40	12.5	26.1
40 to 50	12.5	4.3
50 to 60	8.3	0
60 to 70	12.5	0
70 to 80	4.2	0
>80	0	0

Bat Fatalities

Twenty-three bat fatalities were found during scheduled turbine searches and within search areas, representing four identifiable species. Two additional bats were found incidentally off plot (Table 1 and Figure 7). The most commonly found bat species during the study was hoary bat (*Lasiurus cinereus*; 18 carcasses; 72.0% of all bat fatalities). Other bats found during the study included eastern red bats (*Lasiurus borealis;* three carcasses; 12.0%), little brown bat (*Myotis lucifugus*; two carcasses; 8.0%), and one carcass (4.0%) each of silver-haired bat (*Lasionycteris noctivagans*) and an unidentified bat species.

The most bat fatalities (excluding clearing search carcasses and off plot casualties) were found at Turbine 35 (with three fatalities), followed by two fatalities each at four turbines (turbines 26, 28, 29, 36; Figures 7 and 8). Most of the turbines with multiple bat fatalities were located in the southern part of the facility. Nearly all of the bat fatalities (95.7%) were found within 40 m [131 ft] of the search turbine (Table 3 and Figure 9). The majority of bat fatalities occurred from July to early September (Figure 10).

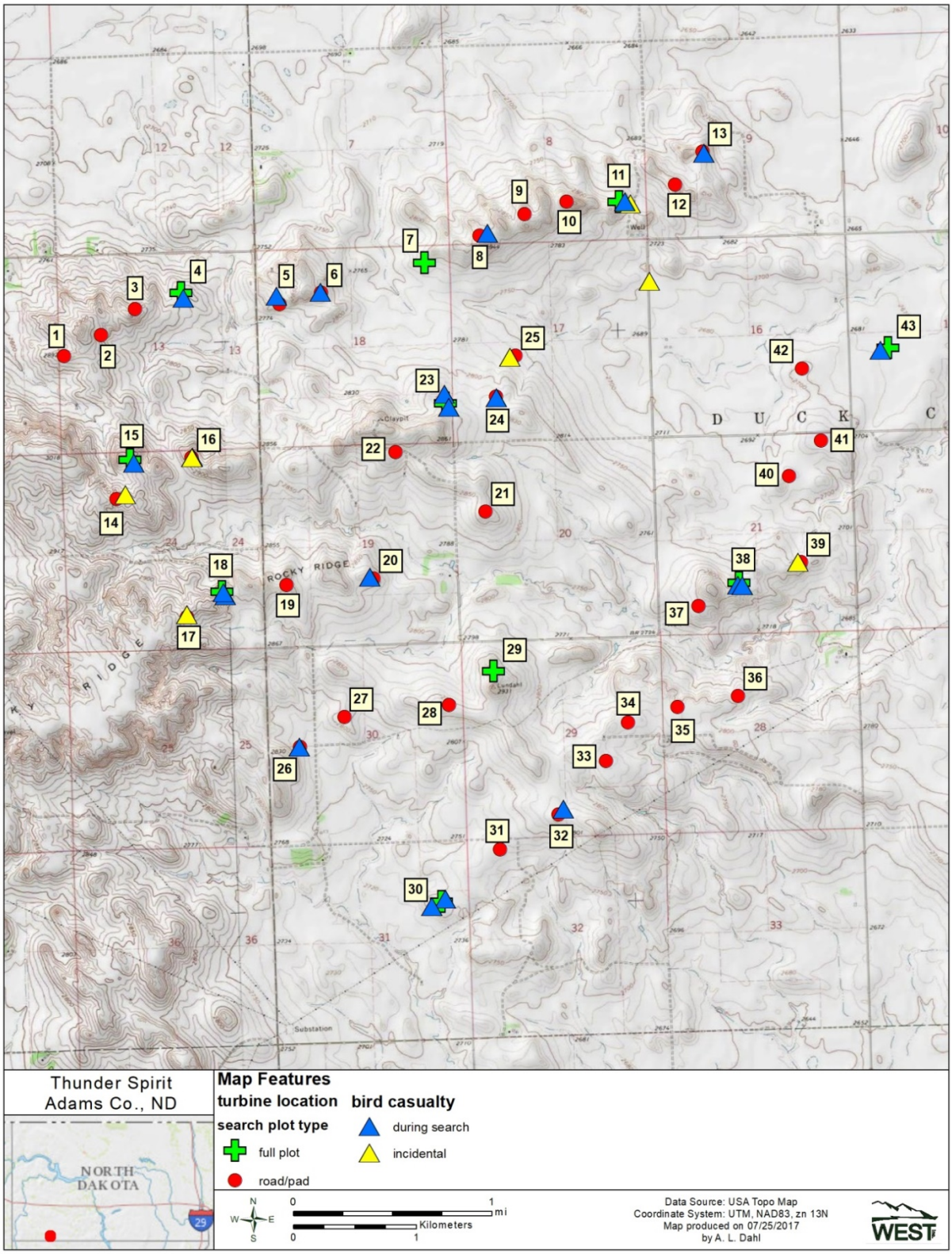

Figure 3. Location of all bird casualties, excluding clearing search carcasses, found at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 4, 2016 to February 1, 2017.

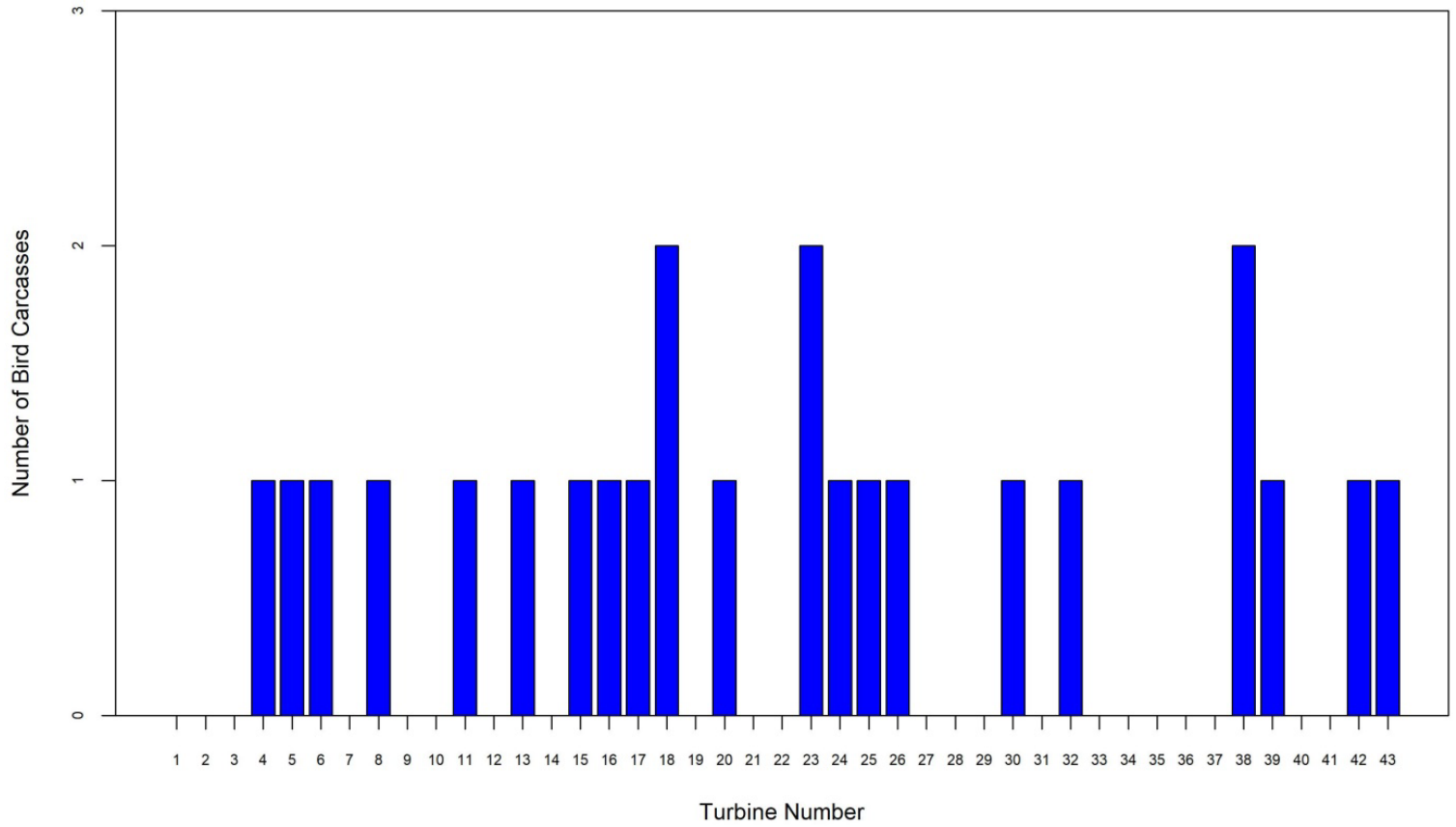

Figure 4. Number of bird casualties by turbine found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota from April 5, 2016 to February 1, 2017.

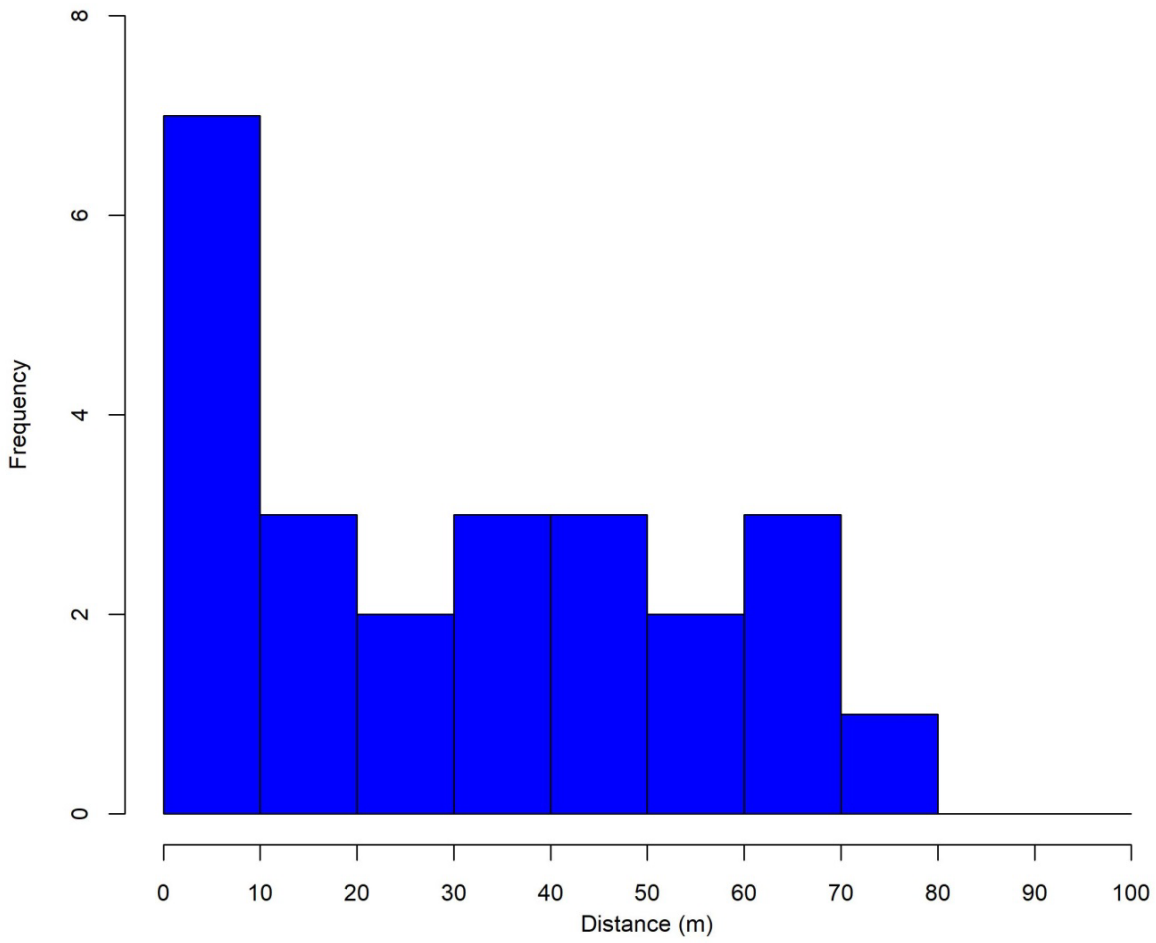

Figure 5. Distance (meters [m]) of bird casualties (number of individuals) from the turbine found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

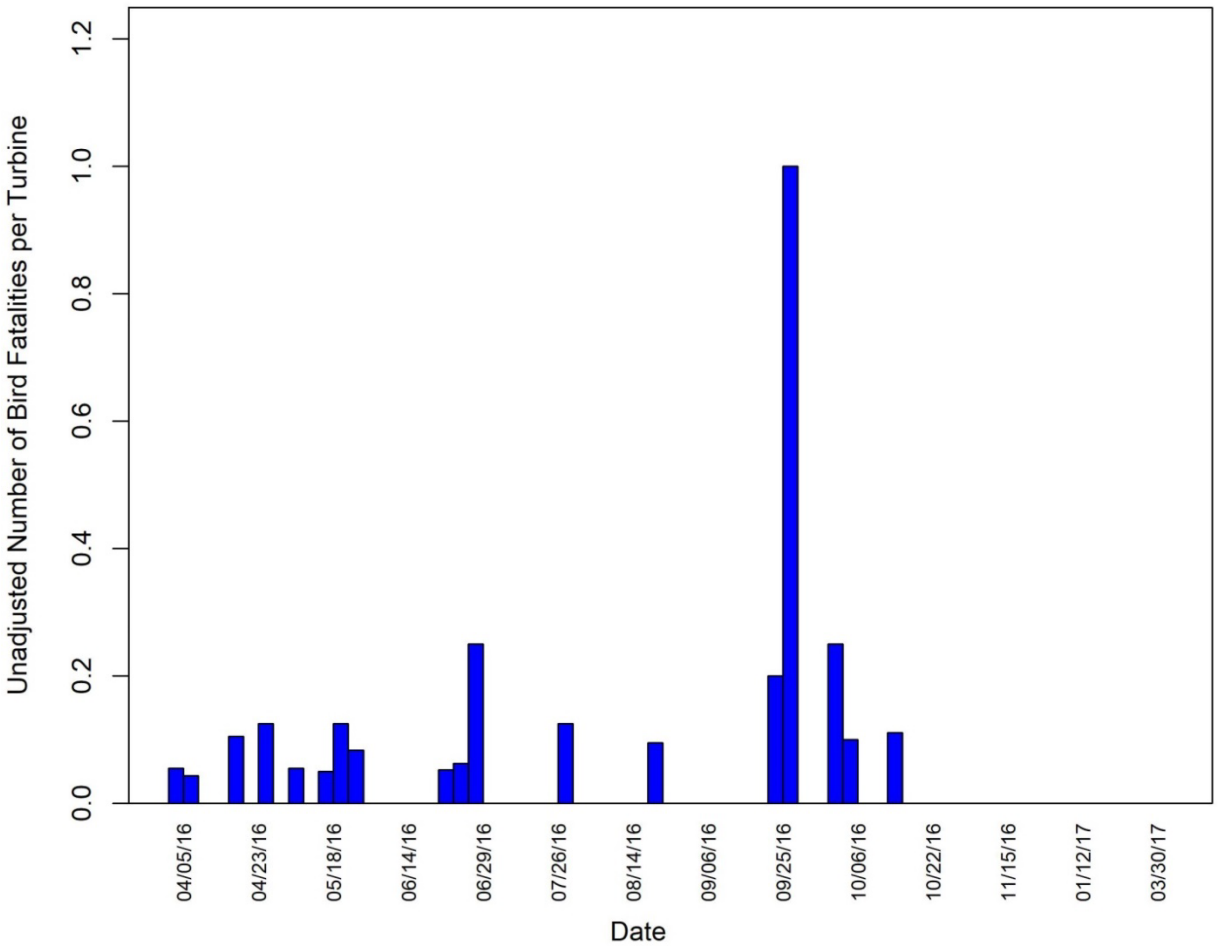

Figure 6. Timing of bird casualties found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

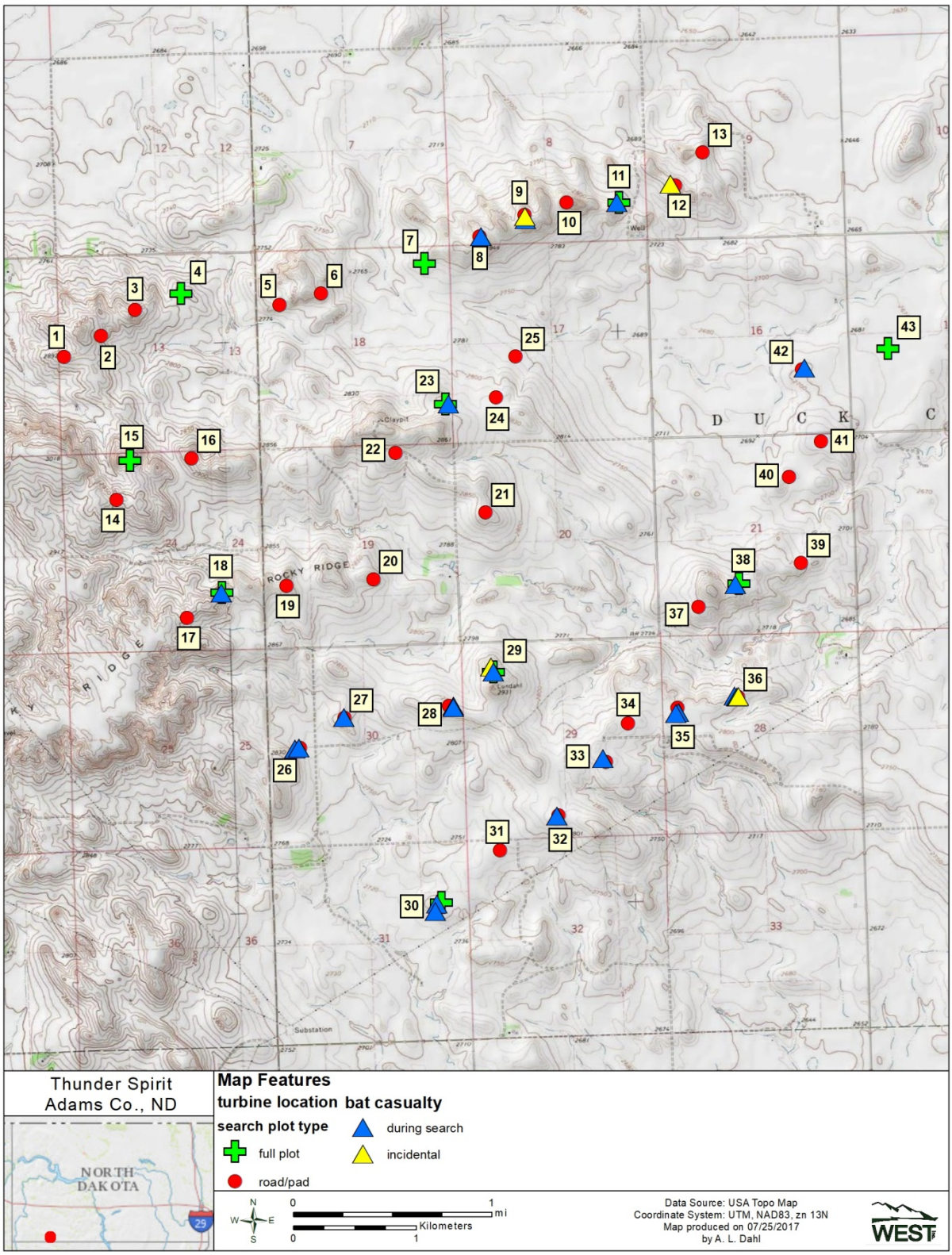

Figure 7. Location of all bat casualties found at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

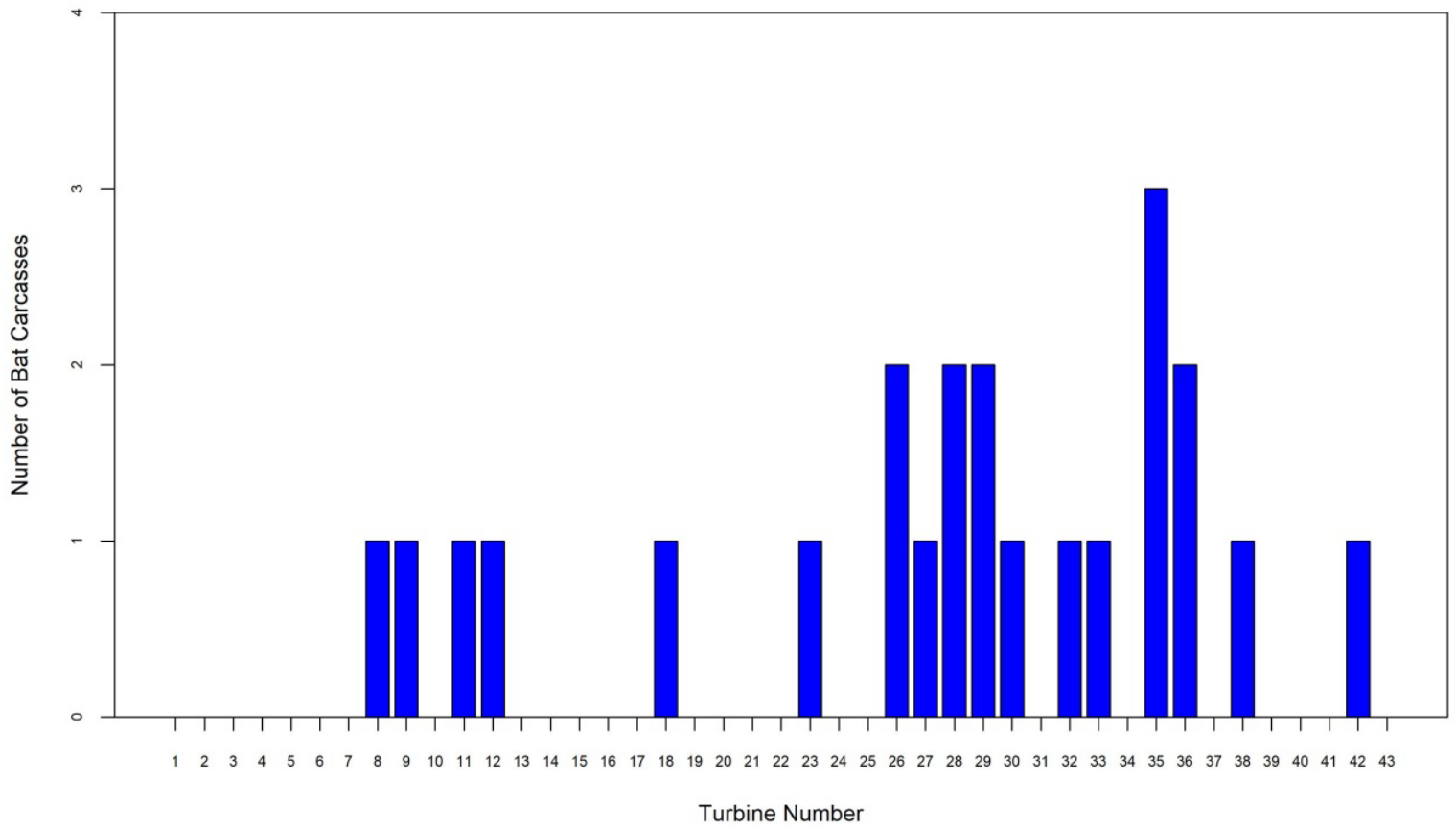

Figure 8. Number of bat casualties by turbine found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

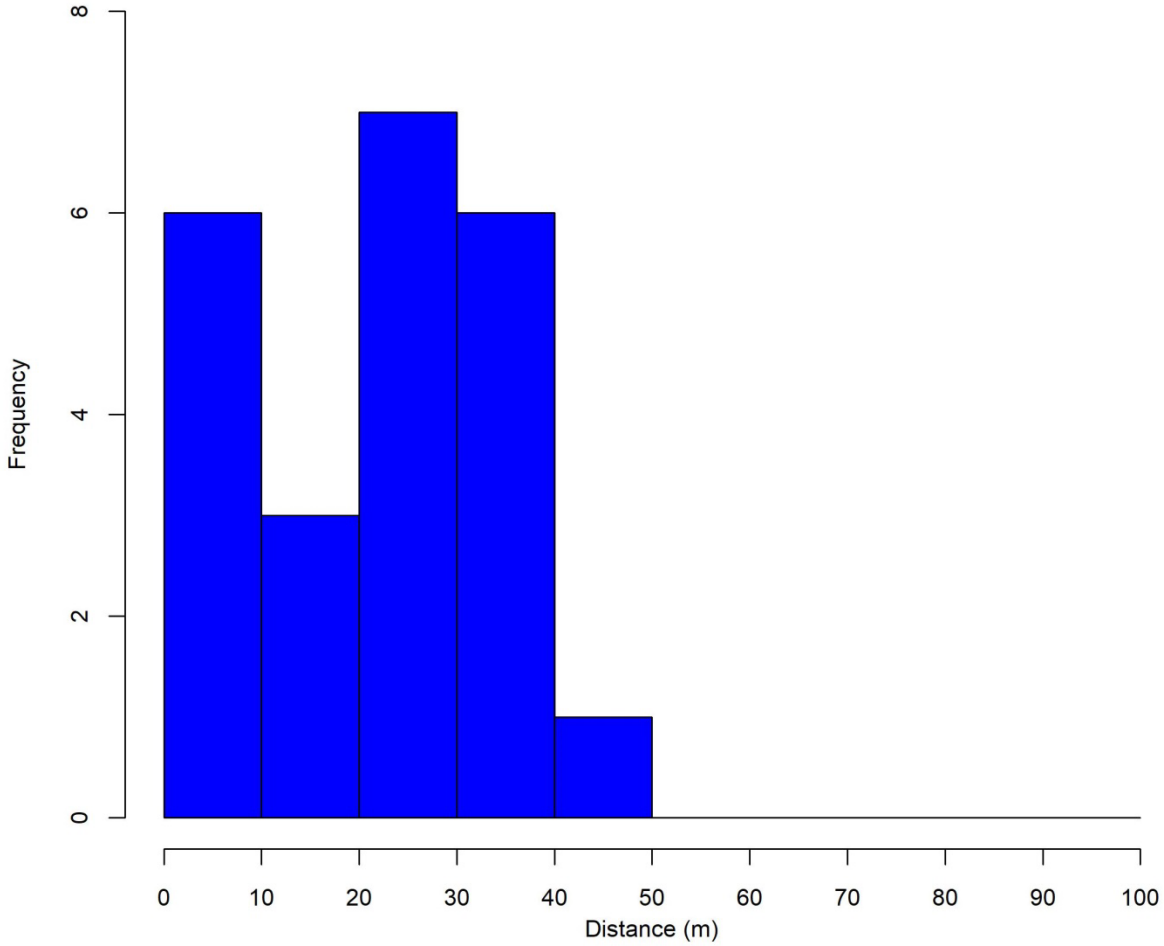

Figure 9. Distance (meters [m]) of bat casualties (number of individuals) from the turbine found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

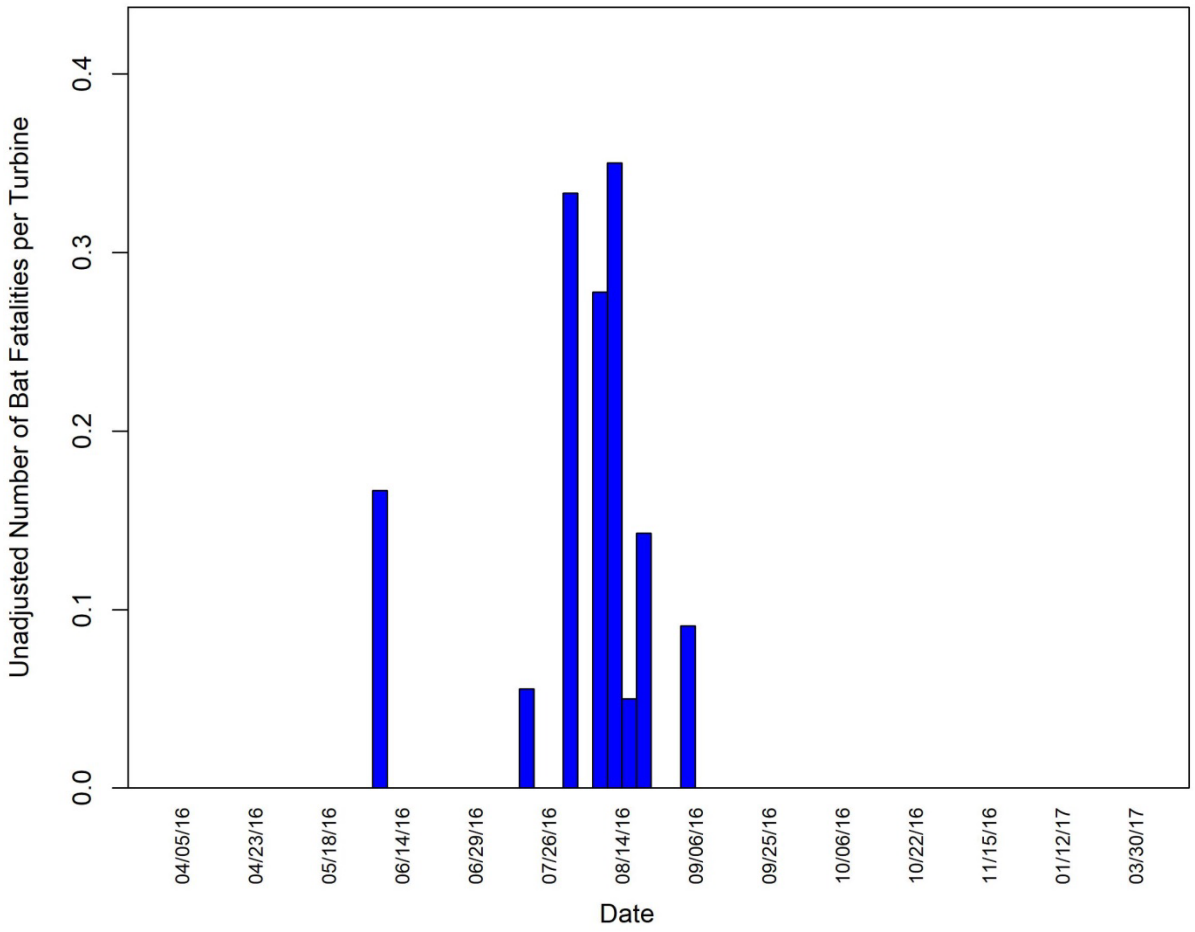

Figure 10. Timing of bat casualties found during scheduled searches or incidentally on turbine search plots at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

Searcher Efficiency Trials

Searcher efficiency trials were conducted on 11 days throughout the study period. A total of 146 bird and bat carcasses (59 small birds, 53 large birds, and 34 bats) were placed for trials, mainly in spring, summer, and fall (Table 4). Although a few carcasses were placed for trials in winter, none of them were available to be found by the searcher due to snow. The searcher efficiency rate across seasons was 67.6% for small birds, 85.7% for large birds, and 30.8% for bats (Table 4). Bat carcasses were only placed for trials in two seasons—summer and fall.

For the modified Huso estimator, models were fit to determine which explanatory variable (i.e., season, size, or none) provided the best model for estimating searcher efficiency based on AICc values. The model with the explanatory variable, null, has the lowest AICc value for large and small birds, whereas the lowest AICc value for bats was season (Table 5).

Table 4. Searcher efficiency results as a function of season and carcass size at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota from April 5, 2016 to February 1, 2017.

Size Class	Season	# Placed	# Available	# Found	% Found
Small Birds	spring	17	8	7	87.5
	summer	17	12	9	75.0
	fall	20	17	9	52.9
	winter	5	0	0	0
Overall Small Birds		**59**	**37**	**25**	**67.6**
Large Birds	spring	13	10	9	90.0
	summer	16	13	12	92.3
	fall	20	19	14	73.4
	winter	4	0	1	0
Overall Large Birds		**53**	**42**	**36**	**85.7**
Bats	summer	14	10	5	50.0
	fall	20	16	3	18.8
Overall Bats		**34**	**26**	**8**	**30.8**

Table 5. AICc model results used to select the best model variable to include for estimating Huso searcher efficiency rates at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Size Class	Explanatory variables	AICc	Winning Model
Small Birds	response ~ 1	48.74	✓
	response ~ Season	49.76	
	response ~ Plot Search Type	50.26	
	response ~ Plot Search Type + Season	51.67	
Large Birds	response ~ 1	39.95	✓
	response ~ Plot Search Type	40.57	
	response ~ Season	42.08	
	response ~ Plot Search Type + Season	43.41	
Bats	response ~ Season	33.83	✓
	response ~ 1	34.26	
	response ~ Plot Search Type + Season	35.98	
	response ~ Plot Search Type	36.43	

Carcass Persistence Trials

A total of 150 carcasses were placed for carcass persistence trials throughout the year, including 71 large birds, 40 small birds, and 39 bats; no bats were placed for trials in the winter season. By day 7, approximately 50% of large birds and 40% of small birds remained where they were placed, whereas less than 10% of bats remained (Figure 11). By day 21, roughly 30% of large bird carcasses, 18% of small bird carcasses, and less than 5% of bat carcasses remained.

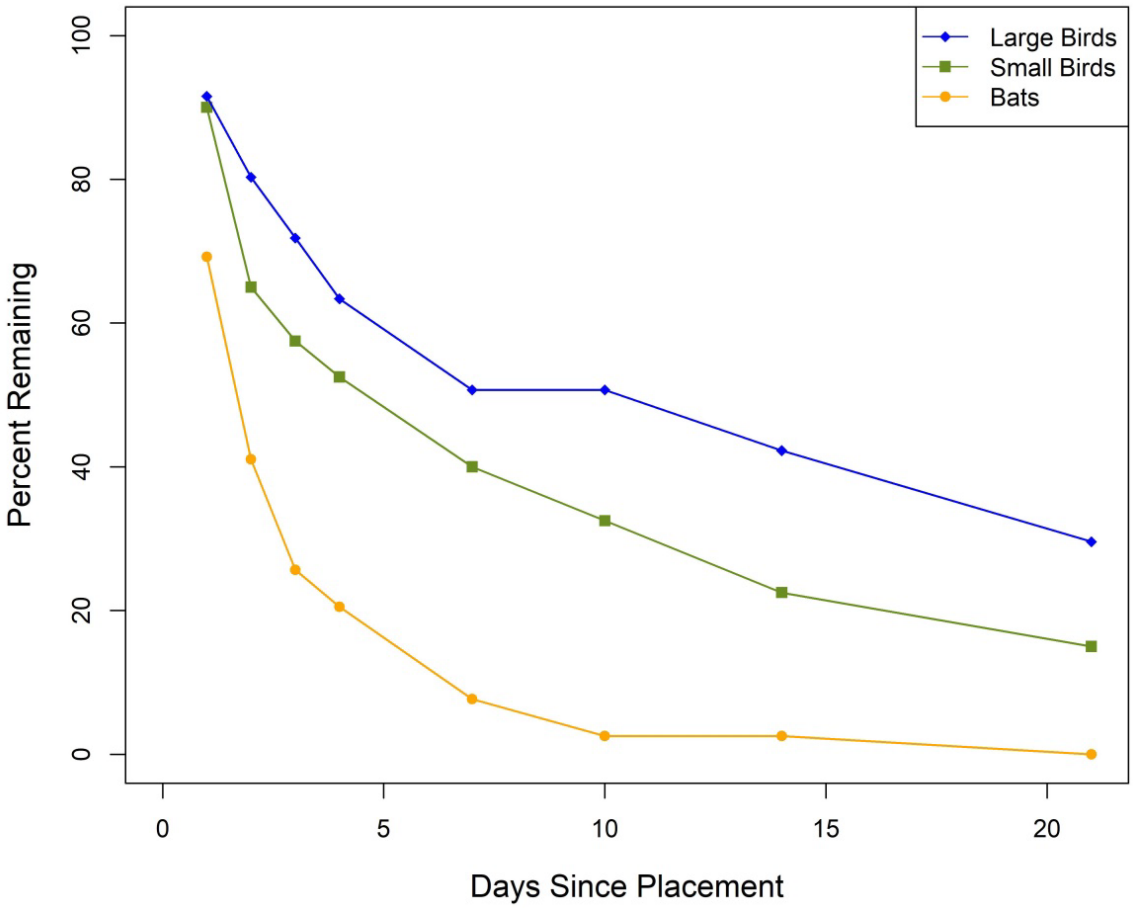

Figure 11. Carcass removal rates (percent of carcasses remaining on various days since placement) at the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Carcass Persistence Models

Models were fit for combinations of distribution (i.e., Weibull, exponential, log-logistic, and lognormal) and explanatory variables (i.e., season or none) and AICc values were used to determine the best model. Season consistently had the lowest AICc value for bat and small bird distributions, whereas the null distribution had the lowest AICc value for large birds; therefore, carcass persistence rates were calculated based on size class (Table 6).

Estimated Carcass Persistence Time

Average carcass persistence times were calculated for each size class (Table 6). Large bird data were pooled across season (season = null) and average carcass persistence time was 8.53 days. Small bird average carcass persistence time varied by season and averaged 1.27 days in spring, 3.64 days in summer, 7.23 days in fall, and 14.75 days in winter. Bat carcass persistence also varied by season and averaged 1.87 days in summer and 3.82 days in fall.

Table 6. Carcass persistence modeling results for the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Size Class	Season	Distribution	Predicted Values	Scale
Small Birds	Spring	Lognormal	1.27	1.41
	Summer	Lognormal	3.64	1.41
	Fall	Lognormal	7.23	1.41
	Winter	Lognormal	14.75	1.41
Large Birds	Null	Lognormal	8.53	1.78
Bat	Summer	Exponential	1.87	1.0
	Fall	Exponential	3.82	1.0

Censored Carcasses

The Huso method of estimating fatality rates censors (excludes) carcasses of birds or bats that are estimated to have been killed longer than the search interval (Table 7). At TSWEF, no carcasses were excluded based on the estimated time of death.

Table 7. Estimated time of death for fatalities, by size class, found at the Thunder Spirit Wind Energy Facility Adams County, North Dakota, from April 5, 2016 to February 1, 2017.

Size Class	Estimated time of Death	Number of Fatalities	% Composition
Small Birds	last night	1	11.1
	2-3 days	4	44.4
	4-7 days	0	0
	7-14 days	4	44.4
	>2 weeks	0	0
	>month	0	0
	unknown	0	0
Large Birds	last night	1	6.7
	2-3 days	5	33.3
	4-7 days	1	6.7
	7-14 days	7	46.7
	>2 weeks	0	0
	>month	0	0
	unknown	0	0
Bats	last night	12	52.2
	2-3 days	2	8.7
	4-7 days	2	8.7
	7-14 days	6	26.1
	>2 weeks	0	0
	>month	0	0
	unknown	1	4.3

Adjusted Fatality Estimates

Fatality estimates and 90% confidence intervals were calculated for birds and bats in each season for full plot and road and pad searches (Table 8; Appendices B and C). No winter adjusted fatality estimates were calculated because no bird or bat mortalities were found in winter. For more details concerning correction factors and confidence intervals for both bird and bat fatality estimates, refer to Appendix B and Appendix C.

Search Area Adjustment

Full plot search area correction factor (search area adjustment) for small birds was 0.951; correction factor was 0.957 for large birds and bats (Appendices B and C). The road and pad correction factor for small birds was 0.315; the correction factor was 0.272 for large birds and 0.359 for bats (Appendices B and C).

Observer Detection

Small bird observer detection (based on searcher efficiency trials) was 0.676 for small birds, 0.833 for large birds, and 0.308 for bats (Appendices B and C). The same rate was used across seasons for small and large birds, and bats.

Mean Carcass Persistence Probabilities

The calculated probability of a small bird carcass persisting through the search interval ranged from 0.18 in the spring to 0.67 in the winter, indicating quicker removal times in the spring relative to winter. For large birds the calculated probability of a carcass persisting through the search interval ranged from 0.54 in the winter to 0.58 in the fall. For bats, the calculated probability of a bat carcass persisting through the search interval was 0.12 in the summer and 0.26 in the fall. Interpretation of these numbers is as follows; a value of 0.12 in summer for bats indicates that on average a bat carcass in summer has a 12% chance of persisting through the search interval.

Average Probability of Carcass Availability and Detected

For small birds, the probability that a carcass would remain in the search plot and be found by a searcher (average probability of carcass availability and detected) was ranged from 0.12 in spring to 0.46 in winter for both search plot types (Appendices B and C). For large birds, values ranged from 0.45 in winter to 0.48 in fall. The average probability of a bat carcass being available and detected was 0.04 in summer and 0.08 in fall.

Small Birds

The estimated adjusted fatality rates (fatalities/turbine/search type/season) for small birds on full plots was 0.39 in summer and 0.97 in fall. Road and pad adjusted fatality rates for small birds ranged from 0.31 in summer to 1.38 in spring. Combining all seasons, the overall estimated small bird fatality rate in the TSWEF was 2.00 small birds/turbine/year or 0.80 small birds/MW/year (Table 8).

Large Birds

The estimated fatality rates for large birds on full plots were higher during the fall (0.72) and lower during summer (0.41) and spring (0.44; Appendix B). Large bird fatality rates on roads and pads were 0.88 in summer, 0.45 in fall, and 0.43 in spring. Combining all seasons, the overall estimated large bird fatality rate was 1.72 birds/turbine/year or 0.69 birds/MW/year (Table 8).

Raptors

Estimated fatality rates for raptors on full plots were relatively similar in spring (0.22) and in fall (0.24; Appendix B). Estimated fatality rates for raptors road and pads was 0.45 in summer. The estimated annual raptor fatality rate was 0.45 raptors/turbine/year or 0.18 raptors/MW/year (Table 8).

All Birds

Combining all seasons, the overall estimated all bird fatality rate within the TSWEF was 3.71 birds/turbine/year or 1.49 birds/MW/year (Table 8).

Bats

Estimated fatality rates for bats on full plots was 19.25 in summer and 2.51 in fall. Road and pad fatality rates were 30.25 in summer and 4.59 in fall. No bat fatalities were found in spring or winter. Combining all seasons and search types, the overall estimated bat fatality rate within the TSWEF was 31.80 bats/turbine/year or 12.72 bats/MW/year (Table 8).

Table 8. Adjusted bird and bat fatality estimates by size class for the Thunder Spirit Wind Energy Facility, Adams County, North Dakota from April 5, 2016 to February 1, 2017.

Size Class	Corrected Fatality Estimate
	# fatalities/turbine/year
Small Birds	2.00
Large Birds	1.72
Raptors	0.45
All Birds	3.71
Bats	31.80
	# fatalities/MW/year
Small Birds	0.80
Large Birds	0.69
Raptors	0.18
All Birds	1.49
Bats	12.72

DISCUSSION

One of the main purposes of the post-construction monitoring efforts was to document any impacts to eagles. As such, the survey was designed with a longer search interval (every two weeks) for all turbines. In addition, the monitoring was used to evaluate if impacts for all birds and bats were lower than, higher than, or similar to, other reported regional and national estimates.

Bird Fatalities

No eagles were found during the one year of survey.

The estimated overall bird fatality rate of 1.49 birds/MW/year was within the range of other wind energy facilities in the Midwest (0.27 fatalities to 8.25 birds/MW/year; Figure 12; Appendix D). Of the 39 wind energy facilities included in Figure 12, TSWEF ranked 31st in bird fatality rates, suggesting that bird fatalities are relatively low compared to other wind energy facilities in the Midwest. Based on the relatively small estimate of avian mortality at the TSWEF, it is unlikely that continued operation of this facility will result in any significant impacts to bird populations (Figure 12).

The raptor fatality estimate at the TSWEF (0.18 raptors/MW/year) was within the range and similar to the raptor fatality rates (zero to 0.47 raptors/MW/year) observed in the Midwest (Figure 13). Compared to 36 other facilities with publicly available raptor mortality data, the TSWEF ranked fifth (Appendix D). Although the TSWEF ranked fifth highest in raptor mortality among Midwest facilities, the mortality estimate was relatively small and many projects record a zero estimate as no raptors are found. This suggests that raptor populations are not likely to experience significant impacts because of the continued operation of this facility (Figure 13).

Bird mortalities were mostly passerines, but also included upland game bird, raptor, and waterfowl species. Raptor fatalities were mainly Swainson's hawks. Fatalities were similar to species compositions found at other wind energy facilities (Erickson et al. 2014). Fatalities were observed in spring, summer, and fall with slightly higher mortality during the fall season.

Bat Fatalities

The estimated bat fatality rate at TSWEF of 12.72 bats/MW/year was within the overall range observed at other Midwest sites (0.16 to 30.61 bats/MW/year; Figure 14; Appendix D), but higher than other sites with public data in North or South Dakota (Figure 14). Compared to 48 other wind energy facilities with publicly available bat fatality estimates, the TSWEF ranked seventh (Figure 14). Most bats found were hoary bats. A recent paper by Frick et al. (2017) modeled potential population level impacts to hoary bats from wind projects operating across the country. While the TSWEP in and of itself is unlikely to impact hoary bat populations, overall impacts from all wind projects are unknown.

All bat fatalities were observed in summer and fall seasons with the majority of carcasses (12) observed on August 13 and 14, 2017. This timing is consistent with results from other bat fatality

studies that have shown peak mortality from August to September and lower mortality in spring and early summer (Johnson 2005, Arnett et al. 2008). The timing suggests that most of the fatalities at TSWEF were likely fall migrants. Most bat fatalities were found in the southern portion of the wind facility but reasons for this are unclear.

While the bat fatality rate at TSWEF was at that higher end of the range from other Midwest projects, the monitoring completed at TSWEF was implemented with the primary focus being on evaluating potential impacts to eagles. Given the primary focus, surveys at TSWEF were conducted every other week. This sampling plan was designed based on carcass persistent time for large birds (e.g., eagles) and not for bats. For the TSWEF, large bird average carcass persistence time was 8.53 days, whereas for bat carcasses the persistence time averaged 1.87 days in summer and 3.82 days in fall. Carcasses or species groups with shorter persistence times should be surveyed on a shorter time period (e.g., for bats sampling should be done weekly or even as much as daily) to achieve a more confident fatality rate estimate. The shorter persistence time as well as a lower searcher efficiency rate compared to larger birds (i.e., bats are harder to find than large birds), results in the very low probability of a bat being available and detected of 0.04 in summer and 0.08 in fall. The low average probability of carcasses being available and detected result in very high inflation factors for bat carcasses found.

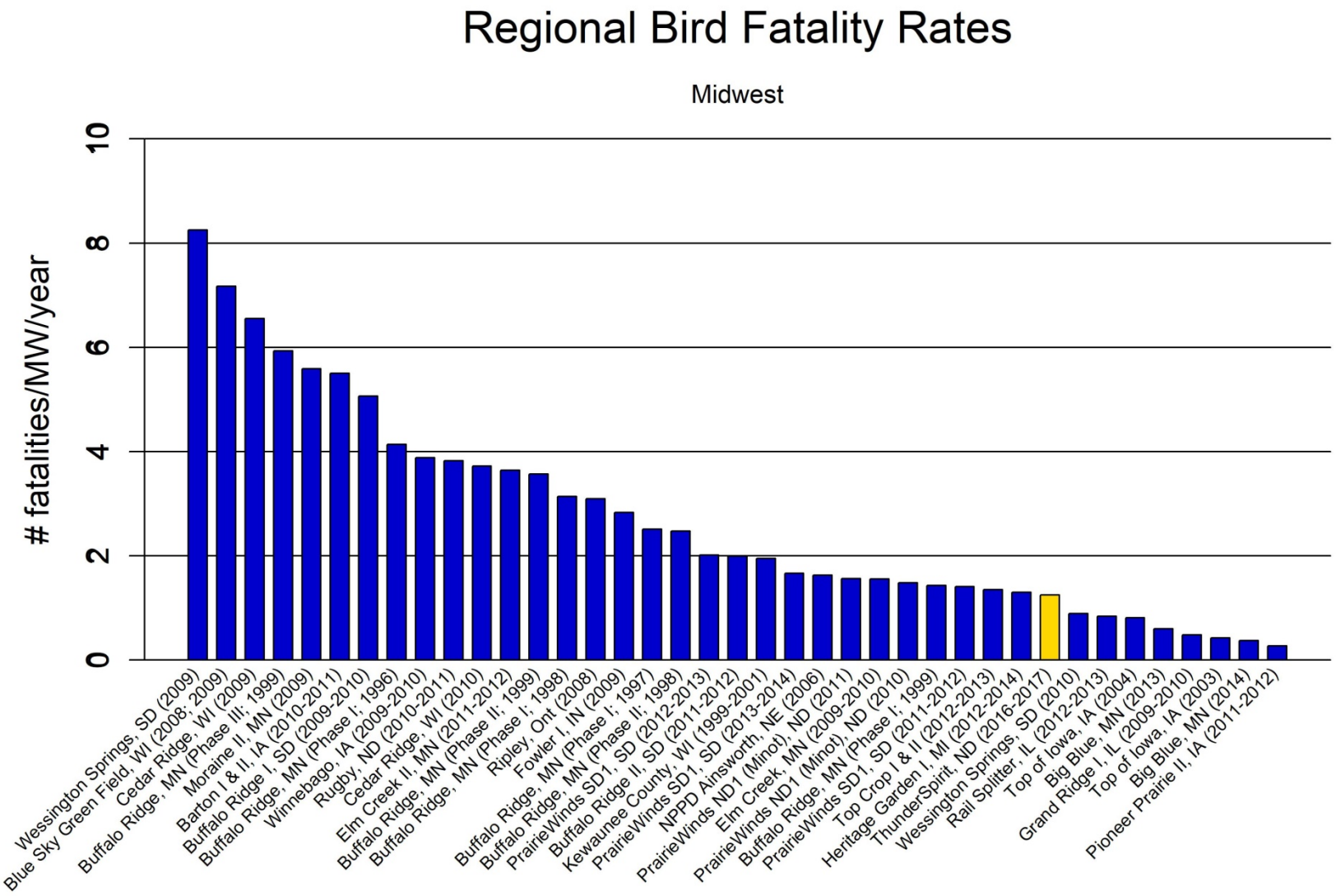

Figure 12. Fatality rates for all birds (number of bird fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Figure 12 (*continued*). Fatality rates for all birds (number of bird fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Data from the following sources:

Wind Energy Facility	Reference	Wind Energy Facility	Reference	Wind Energy Facility	Reference
ThunderSpirit, ND (2016-2017)	This study				
Wessington Springs, SD (09)	Derby et al. 2010c	Buffalo Ridge, MN (Phase I; 98)	Johnson et al. 2000	Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000
Blue Sky Green Field, WI (08; 09)	Gruver et al. 2009	Ripley, Ont (08)	Jacques Whitford 2009	PrairieWinds SD1, SD (11-12)	Derby et al. 2012c
Cedar Ridge, WI (09)	BHE Environmental 2010	Fowler I, IN (09)	Johnson et al. 2010a	Top Crop I & II (12-13)	Good et al. 2013c
Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2000	Buffalo Ridge, MN (Phase I; 97)	Johnson et al. 2000	Heritage Garden I, MI (12-14)	Kerlinger et al. 2014
Moraine II, MN (09)	Derby et al. 2010f	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Wessington Springs, SD (10)	Derby et al. 2011a
Barton I & II, IA (10-11)	Derby et al. 2011b	PrairieWinds SD1, SD (12-13)	Derby et al. 2013	Rail Splitter, IL (12-13)	Good et al. 2013b
Buffalo Ridge I, SD (09-10)	Derby et al. 2010d	Buffalo Ridge II, SD (11-12)	Derby et al. 2012a	Top of Iowa, IA (04)	Jain 2005
Buffalo Ridge, MN (Phase I; 96)	Johnson et al. 2000	Kewaunee County, WI (99-01)	Howe et al. 2002	Big Blue, MN (13)	Fagen Engineering 2014
Winnebago, IA (09-10)	Derby et al. 2010g	PrairieWinds SD1, SD (13-14)	Derby et al. 2014	Grand Ridge I, IL (09-10)	Derby et al. 2010a
Rugby, ND (10-11)	Derby et al. 2011c	NPPD Ainsworth, NE (06)	Derby et al. 2007	Top of Iowa, IA (03)	Jain 2005
Cedar Ridge, WI (10)	BHE Environmental 2011	PrairieWinds ND1, ND (11)	Derby et al. 2012d	Big Blue, MN (14)	Fagen Engineering 2015
Elm Creek II, MN (11-12)	Derby et al. 2012b	Elm Creek, MN (09-10)	Derby et al. 2010e	Pioneer Prairie II, IA (11-12)	Chodachek et al. 2012
Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	PrairieWinds ND1, ND (10)	Derby et al. 2011d		

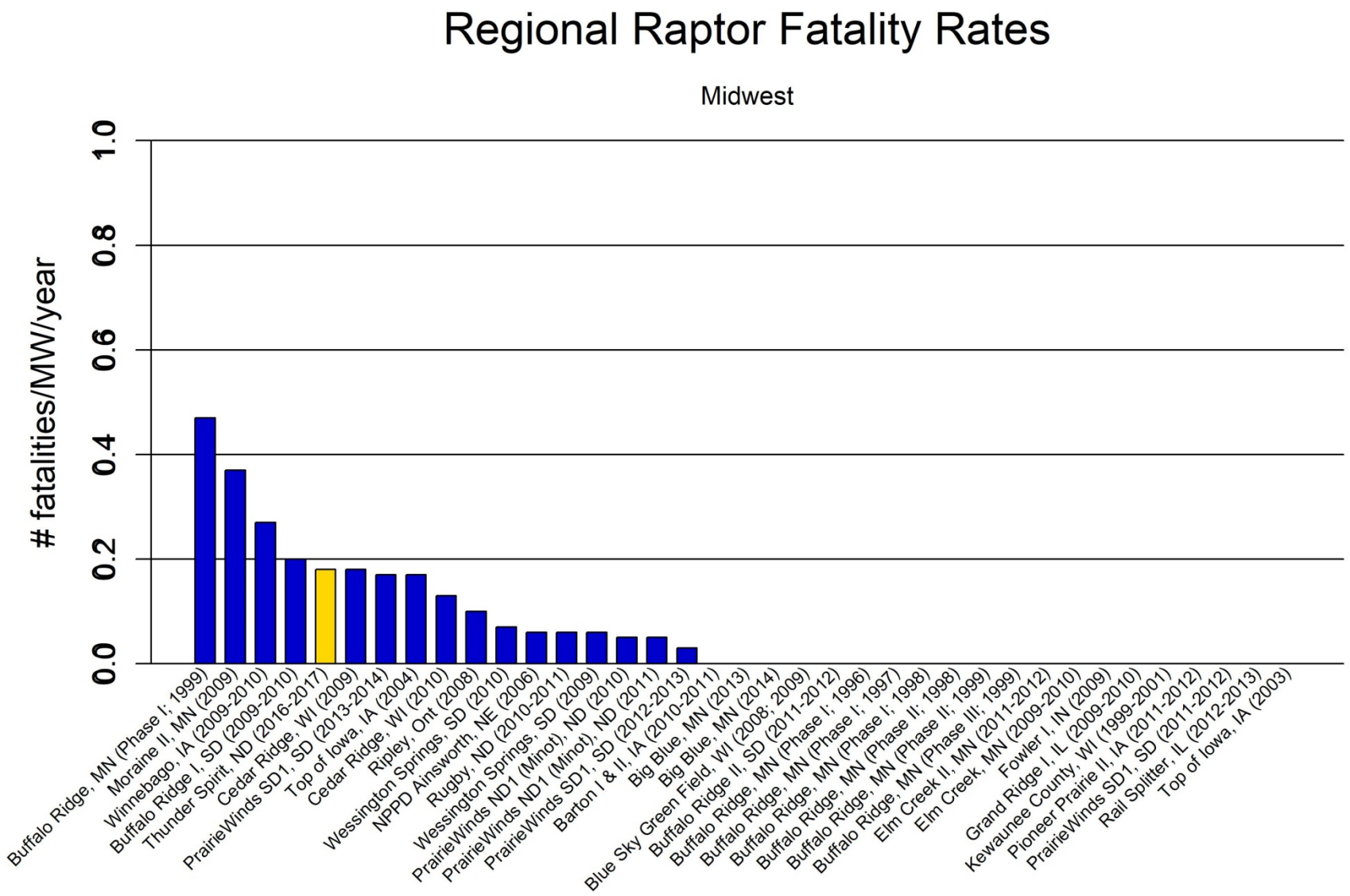

Figure 13. Raptor fatality rates (number of raptor fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Figure 13 (*continued*). Raptor fatality rates (number of raptor fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Data from the following sources:

Wind Energy Facility	Reference	Wind Energy Facility	Reference	Wind Energy Facility	Reference
Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000	Wessington Springs, SD (09)	Derby et al. 2010c	Barton I & II, IA (10-11)	Derby et al. 2011b
Moraine II, MN (09)	Derby et al. 2010f	PrairieWinds ND1 (Minot), ND (11)	Derby et al. 2011d	PrairieWinds SD1, SD (11-12)	Derby et al. 2012c
Winnebago, IA (09-10)	Derby et al. 2010g	PrairieWinds ND1 (Minot), ND (10)	Derby et al. 2012d	Kewaunee County, WI (99-01)	Howe et al. 2002
Buffalo Ridge I, SD (09-10)	Derby et al. 2010d	PrairieWinds SD1, SD (12-13)	Derby et al. 2013	Buffalo Ridge II, SD (11-12)	Derby et al. 2012a
Cedar Ridge, WI (09)	BHE Environmental 2010	Elm Creek, MN (09-10)	Derby et al. 2010e	Buffalo Ridge, MN (Phase I; 96)	Johnson et al. 2000
PrairieWinds SD1, SD (13-14)	Derby et al. 2014	Rail Splitter, IL (12-13)	Good et al. 2013b	Buffalo Ridge, MN (Phase I; 97)	Johnson et al. 2000
Top of Iowa, IA (04)	Jain 2005	Pioneer Prairie II, IA (11-12)	Chodachek et al. 2012	Buffalo Ridge, MN (Phase I; 98)	Johnson et al. 2000
Cedar Ridge, WI (10)	BHE Environmental 2011	Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2000	Fowler I, IN (09)	Johnson et al. 2010a
Ripley, Ont (08)	Jacques Whitford 2009	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Big Blue, MN (13)	Fagen Engineering 2014
Wessington Springs, SD (10)	Derby et al. 2011a	Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	Big Blue, MN (14)	Fagen Engineering 2015
Rugby, ND (10-11)	Derby et al. 2011c	Blue Sky Green Field, WI (08; 09)	Gruver et al. 2009	Top of Iowa, IA (03)	Jain 2005
NPPD Ainsworth, NE (06)	Derby et al. 2007	Elm Creek II, MN (11-12)	Derby et al. 2012b	Grand Ridge I, IL (09-10)	Derby et al. 2010a

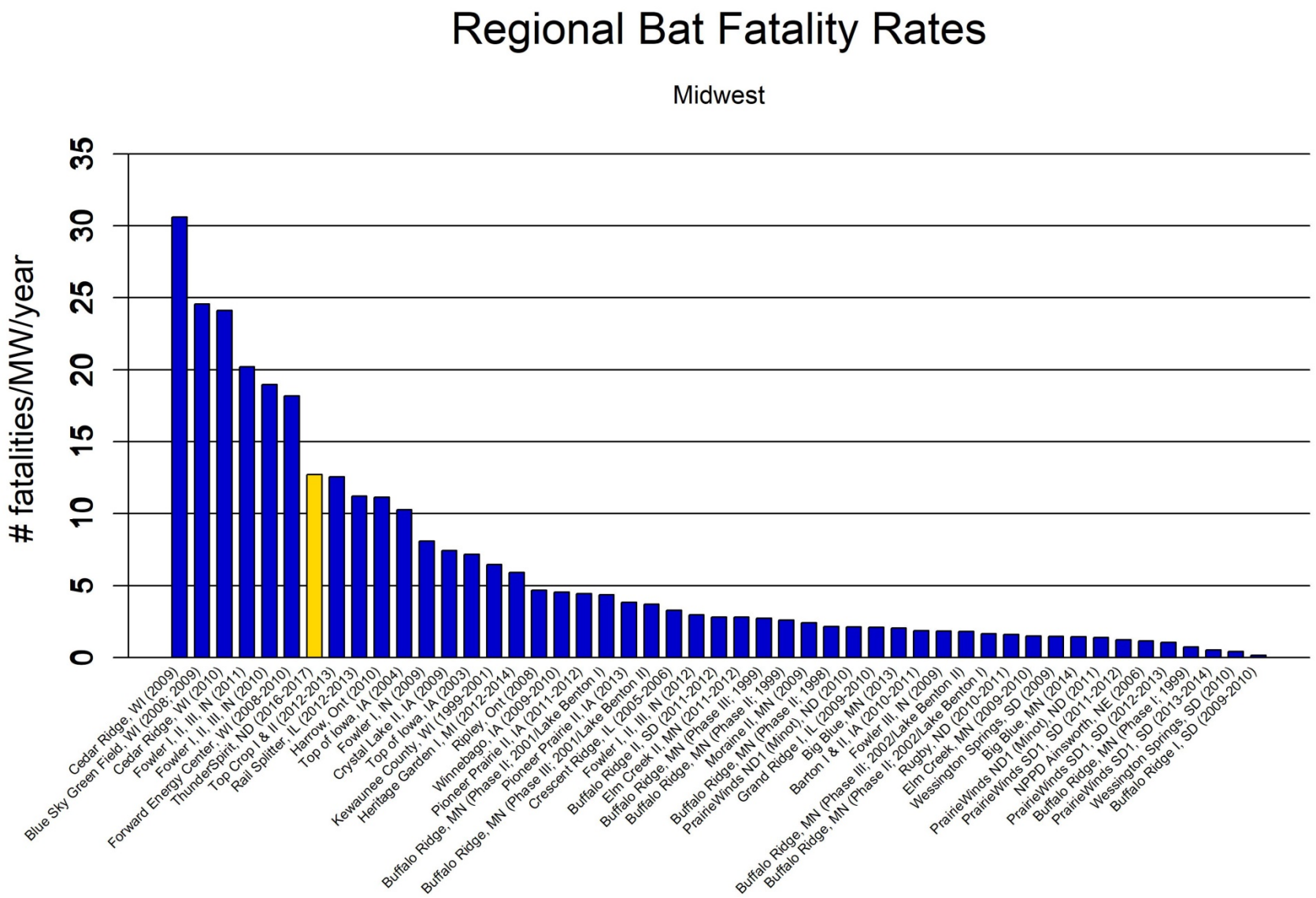

Figure 14. Bat fatality rates (number of bat fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Figure 14 (*continued*). Bat fatality rates (number of bat fatalities per megawatt per year) from publicly available studies conducted at wind energy facilities in the Midwest region of North America.

Data from the following sources:

Wind Energy Facility	Reference	Wind Energy Facility	Reference	Wind Energy Facility	Reference
ThunderSpirit, ND (2106-2017)	This study				
Cedar Ridge, WI (09)	BHE Environmental 2010	Winnebago, IA (09-10)	Derby et al. 2010g	Barton I & II, IA (10-11)	Derby et al. 2011b
Blue Sky Green Field, WI (08; 09)	Gruver et al. 2009	Pioneer Prairie II, IA (11-12)	Chodachek et al. 2012	Fowler III, IN (09)	Johnson et al. 2010b
Cedar Ridge, WI (10)	BHE Environmental 2011	Buffalo Ridge, MN (Phase II; 01/Lake Benton I)	Johnson et al. 2004	Buffalo Ridge, MN (Phase III; 02/Lake Benton II)	Johnson et al. 2004
Fowler I, II, III, IN (11)	Good et al. 2012	Pioneer Prairie II, IA (13)	Chodachek et al. 2014	Buffalo Ridge, MN (Phase II; 02/Lake Benton I)	Johnson et al. 2004
Fowler I, II, III, IN (10)	Good et al. 2011	Buffalo Ridge, MN (Phase III; 01/Lake Benton II)	Johnson et al. 2004	Rugby, ND (10-11)	Derby et al. 2011c
Forward Energy Center, WI (08-10)	Grodsky and Drake 2011	Crescent Ridge, IL (05-06)	Kerlinger et al. 2007	Elm Creek, MN (09-10)	Derby et al. 2010e
Top Crop I & II, IL (12-13)	Good et al. 2013c	Fowler I, II, III, IN (12)	Good et al. 2013a	Wessington Springs, SD (09)	Derby et al. 2010c
Rail Splitter, IL (12-13)	Good et al. 2013b	Elm Creek II, MN (11-12)	Derby et al. 2012b	Big Blue, MN (14)	Fagen Engineering 2015
Harrow, Ont (10)	Natural Resource Solutions Inc. (NRSI) 2011	Buffalo Ridge II, SD (11-12)	Derby et al. 2012a	PrairieWinds ND1 (Minot), ND (11)	Derby et al. 2012d
Top of Iowa, IA (04)	Jain 2005	Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2000	PrairieWinds SD1, SD (11-12)	Derby et al. 2012c
Fowler I, IN (09)	Johnson et al. 2010a	Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	NPPD Ainsworth, NE (06)	Derby et al. 2007
Crystal Lake II, IA (09)	Derby et al. 2010b	Moraine II, MN (09)	Derby et al. 2010f	PrairieWinds SD1, SD (12-13)	Derby et al. 2013
Top of Iowa, IA (03)	Jain 2005	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000
Kewaunee County, WI (99-01)	Howe et al. 2002	PrairieWinds ND1 (Minot), ND (10)	Derby et al. 2011d	PrairieWinds SD1, SD (13-14)	Derby et al. 2014
Heritage Garden I, MI (12-14)	Kerlinger et al. 2014	Grand Ridge I, IL (09-10)	Derby et al. 2010a	Wessington Springs, SD (10)	Derby et al. 2011a
Ripley, Ont (08)	Jacques Whitford 2009	Big Blue, MN (13)	Fagen Engineering 2014	Buffalo Ridge I, SD (09-10)	Derby et al. 2010d

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Appendix A. Complete Fatality List for the Thunder Spirit Wind Energy Facility

Appendix A. Complete fatality listing (including clearing search) for the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Date	Common Name	Location	Distance from Turbine (meters)	Type of Find	Search Type	Condition
3/21/2016	European starling			carcass search	clearing search	
3/21/2016	sharp-tailed grouse			carcass search	clearing search	
4/5/2016	dark-eyed junco	32	56	carcass search	road/pad	intact
4/6/2016	ring-necked pheasant	26	1	carcass search	road/pad	scavenged
4/22/2016	horned lark	13	8	carcass search	road/pad	scavenged
4/22/2016	Swainson's hawk	43	63	carcass search	full plot	intact
5/6/2016	Mallard	17	19	incidental	road/pad	scavenged
5/8/2016	Mallard	4	46	carcass search	full plot	dismembered
5/18/2016	blue-winged teal	6	6	carcass search	road/pad	dismembered
5/19/2016	brown thrasher	20	31	carcass search	road/pad	intact
5/19/2016	Swainson's hawk	39	25	incidental	road/pad	dismembered
6/1/2016	Mallard	25	42	incidental	road/pad	scavenged
6/3/2016	hoary bat	30	33	carcass search	road/pad	intact
6/27/2016	northern flicker	23	70	carcass search	road/pad	feather spot
6/28/2016	gray partridge	15	40	carcass search	full plot	feather spot
6/29/2016	northern harrier	5	63	carcass search	road/pad	scavenged
7/25/2016	hoary bat	35	31	carcass search	road/pad	scavenged
7/27/2016	unidentified blackbird	23	43	carcass search	road/pad	scavenged
7/28/2016	eastern red bat	11	12	carcass search	road/pad	intact
7/28/2016	hoary bat	29	28	incidental	full plot	intact
8/1/2016	hoary bat	35	2	incidental	full plot	scavenged
8/13/2016	hoary bat	26	38	carcass search	road/pad	intact
8/13/2016	hoary bat	18	7	carcass search	road/pad	intact
8/13/2016	hoary bat	8	26	carcass search	road/pad	intact
8/13/2016	hoary bat	9	33	carcass search	full plot	intact
8/13/2016	unidentified bat	26	6	carcass search	road/pad	scavenged
8/14/2016	hoary bat	32	11	carcass search	full plot	scavenged
8/14/2016	hoary bat	33	35	carcass search	road/pad	intact
8/14/2016	hoary bat	35	45	carcass search	full plot	scavenged
8/14/2016	hoary bat	28	21	carcass search	road/pad	scavenged

Appendix A. Complete fatality listing (including clearing search) for the Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

Date	Common Name	Location	Distance from Turbine (meters)	Type of Find	Search Type	Condition
8/14/2016	hoary bat	23	25	carcass search	full plot	scavenged
8/14/2016	hoary bat	28	20	carcass search	road/pad	scavenged
8/14/2016	silver-haired bat	29	1	carcass search	full plot	intact
8/16/2016	western meadowlark	16	3	incidental	road/pad	scavenged
8/23/2016	little brown bat	42	24	carcass search	road/pad	scavenged
8/24/2016	eastern red bat	38	28	carcass search	full plot	intact
8/24/2016	hoary bat	36	28	carcass search	road/pad	intact
8/24/2016	hoary bat	12	35	incidental	road/pad	scavenged
8/24/2016	mourning dove	24	7	carcass search	road/pad	intact
8/24/2016	unidentified sparrow	38	7	carcass search	full plot	scavenged
9/6/2016	hoary bat	36	3	carcass search	road/pad	scavenged
9/13/2016	hoary bat	27	1	carcass search	road/pad	intact
9/15/2016	eastern red bat	9	11	incidental	road/pad	scavenged
9/15/2016	sharp-tailed grouse	16	1	incidental	road/pad	scavenged
9/24/2016	little brown bat	30	86	carcass search	road/pad	scavenged
9/25/2016	Swainson's hawk	38	33	carcass search	full plot	scavenged
9/25/2016	yellow-rumped warbler	11	80	incidental	road/pad	intact
9/26/2016	yellow warbler	18	20	carcass search	full plot	intact
10/5/2016	house sparrow	11	25	carcass search	road/pad	intact
10/5/2016	unidentified hawk	12		incidental	full plot	scavenged
10/6/2016	ring-necked pheasant	30	20	carcass search	road/pad	feather spot
10/13/2016	house sparrow	42	60	incidental	road/pad	intact
10/20/2016	spotted towhee	8	74	carcass search	road/pad	scavenged
10/20/2016	sharp-tailed grouse	18	6	carcass search	full plot	intact
10/22/2016	ring-necked pheasant	30	82	carcass search	road/pad	feather spot

Appendix B. Point Estimates, Lower, and Upper 90% Confidence Intervals for Bird Fatality Rate Estimation at Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017

Appendix B. Point estimates (mean) and lower (ll) and upper (ul) of 90% confidence intervals for bird fatality rate estimation at Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

	Spring			Summer			Fall			Winter		
		90 % CI			90% CI			90% CI			90% CI	
	mean	ll	ul	mean	ll	ul	mean	ll	ul	mean	ll	ul
Search Area Adjustment												
Small Birds												
Full plot	0.951	-	-	0.951	-	-	0.951	-	-	0.951	-	-
Road and pad	0.315	-	-	0.315	-	-	0.315	-	-	0.315	-	-
Large Birds												
Full plot	0.957	-	-	0.957	-	-	0.957	-	-	0.957	-	-
Road and pad	0.272	-	-	0.272	-	-	0.272	-	-	0.272	-	-
Diurnal Raptors												
Full plot	0.957	-	-	0.957	-	-	0.957	-	-	0.957	-	-
Road and pad	0.272	-	-	0.272	-	-	0.272	-	-	0.272	-	-
Observer Detection												
Small Birds												
Full plot	0.676	0.553	0.795	0.676	0.553	0.795	0.676	0.553	0.795	0.676	0.553	0.795
Road and pad	0.676	0.553	0.795	0.676	0.553	0.795	0.676	0.553	0.795	0.676	0.553	0.795
Large Birds												
Full plot	0.833	0.732	0.923	0.833	0.732	0.923	0.833	0.732	0.923	0.833	0.732	0.923
Road and pad	0.833	0.732	0.923	0.833	0.732	0.923	0.833	0.732	0.923	0.833	0.732	0.923
Diurnal Raptors												
Full plot	0.833	-	-	0.833	-	-	0.833	-	-	0.833	-	-
Road and pad	0.833	-	-	0.833	-	-	0.833	-	-	0.833	-	-
Average Persistence Time												
Small Birds												
Full plot	0.177	0.054	0.343	0.381	0.262	0.516	0.551	0.343	0.741	0.673	-	-
Road and pad	0.177	0.054	0.343	0.381	0.262	0.516	0.551	0.343	0.741	0.673	-	-
Large Birds												
Full plot	0.564	0.484	0.632	0.573	0.493	0.640	0.580	0.500	0.647	0.541	0.462	0.610
Road and pad	0.564	0.484	0.632	0.573	0.493	0.640	0.580	0.500	0.647	0.541	0.462	0.610
Diurnal Raptors												
Full plot	0.564	-	-	0.573	-	-	0.580	-	-	0.541	-	-
Road and pad	0.564	-	-	0.573	-	-	0.580	-	-	0.541	-	-
Observed Fatality Rates (fatalities/turbine/season)												
Small Birds												
Full plot	-	-	-	0.100	0	0.300	0.300	0.100	0.600	-	-	-
Road and pad	0.061	0	0.121	0.030	0	0.091	0.061	0	0.121	-	-	-

Appendix B. Point estimates (mean) and lower (ll) and upper (ul) of 90% confidence intervals for bird fatality rate estimation at Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017.

	Spring			Summer			Fall			Winter		
		90 % CI			90% CI			90% CI			90% CI	
	mean	ll	ul	mean	ll	ul	mean	ll	ul	mean	ll	ul
Large Birds												
Full plot	0.200	0	0.400	0.200	0	0.400	0.300	0.100	0.600	-	-	-
Road and pad	0.061	0	0.121	0.121	0.030	0.212	0.061	0	0.121	-	-	-
Diurnal Raptors												
Full plot	0.100	0	0.300	-	-	-	0.100	0	0.300	-	-	-
Road and pad	-	-	-	0.061	0	0.121	-	-	-	-	-	-
Average Probability of Carcass Availability and Detected												
Small Birds												
Full plot	0.120	0.038	0.232	0.258	0.167	0.364	0.373	0.219	0.521	0.455	-	-
Road and pad	0.120	0.038	0.232	0.258	0.167	0.364	0.373	0.219	0.521	0.455	-	-
Large Birds												
Full plot	0.470	0.384	0.546	0.478	0.391	0.555	0.483	0.396	0.561	0.450	0.366	0.526
Road and pad	0.470	0.384	0.546	0.478	0.391	0.555	0.483	0.396	0.561	0.450	0.366	0.526
Diurnal Raptors												
Full plot	0.470	-	-	0.478	-	-	0.483	-	-	0.450	-	-
Road and pad	0.470	-	-	0.478	-	-	0.483	-	-	0.450	-	-
Adjusted Fatality Estimates (fatalities/turbine/search type/season)												
Small Birds												
Full plot	-	-	-	0.391	0	1.245	0.971	0.210	2.364	-	-	-
Road and pad	1.379	0	4.659	0.313	0	0.939	0.499	0	1.312	-	-	-
Large Birds												
Full plot	0.436	0	1.010	0.410	0	0.967	0.724	0.191	1.49	-	-	-
Road and pad	0.426	0	0.898	0.881	0.222	1.648	0.453	0	1.057	-	-	-
Diurnal Raptors												
Full plot	0.218	0	0.667	-	-	-	0.238	0	0.667	-	-	-
Road and pad	-	-	-	0.449	0	0.948	-	-	-	-	-	-

Overall Adjusted Fatality Estimates (fatalities/turbine)			
		90% Confidence Interval	
	Mean	**Lower Limit**	**Upper Limit**
Small Birds	**2.00**	**0.75**	**4.46**
Large Birds	**1.72**	**1.01**	**2.46**
All Birds	**3.71**	**2.30**	**6.26**
Diurnal Raptors	**0.45**	**0.05**	**0.93**

Appendix C. Point Estimates, Lower, and Upper 90% Confidence Intervals for Bat Fatality Rate Estimation at Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017

Appendix C. Point estimates (mean) and lower (ll) and upper (ul) of 90% confidence intervals for bat fatality rate estimation at Thunder Spirit Wind Energy Facility, Adams County, North Dakota, April 5, 2016 to February 1, 2017

	Spring			Summer			Fall			Winter		
		90 % CI			90% CI			90% CI			90% CI	
	mean	ll	ul	mean	ll	ul	mean	ll	ul	mean	ll	ul
Search Area Adjustment												
Bats												
Full plot	0.957	-	-	0.957	-	-	0.957	-	-	0.957	-	-
Road and pad	0.359	-	-	0.359	-	-	0.359	-	-	0.359	-	-
Observer Detection												
Bats												
Full plot	0.308	0.167	0.448	0.308	0.167	0.448	0.308	0.167	0.448	0.308	0.167	0.448
Road and pad	0.308	0.167	0.448	0.308	0.167	0.448	0.308	0.167	0.448	0.308	0.167	0.448
Average Persistence Time												
Bats												
Full plot	-	-	-	0.123	0.082	0.166	0.256	0.139	0.384	-	-	-
Road and pad	-	-	-	0.123	0.082	0.166	0.256	0.139	0.384	-	-	-
Observed Fatality Rates (fatalities/turbine/season)												
Bats												
Full plot	-	-	-	0.600	0.200	1.100	0.100	0.000	0.300	-	-	-
Road and pad	-	-	-	0.333	0.121	0.545	0.152	0.030	0.273	-	-	-
Average Probability of Carcass Availability and Detected												
Bats												
Full plot	-	-	-	0.038	0.019	0.064	0.079	0.033	0.139	-	-	-
Road and pad	-	-	-	0.038	0.019	0.064	0.079	0.033	0.139	-	-	-
Adjusted Fatality Estimates (fatalities/turbine/search type/season)												
Bats												
Full plot	-	-	-	19.245	5.966	49.607	2.511	0	9.534	-	-	-
Road and pad	-	-	-	30.251	10.771	66.854	4.592	1.059	13.245	-	-	-

Overall Adjusted Fatality Estimates (fatalities/turbine)			
		90% Confidence Interval	
	Mean	**Lower Limit**	**Upper Limit**
Bats	**31.80**	**15.55**	**67.10**

Appendix D. Bird, Raptor, and Bat Use and Fatality Summary Tables for Midwest Wind Energy Facilities

Appendix D1. Fatality estimates (number of bird fatalities per megawatt per year) for all bird species from studies conducted at Midwest wind energy facilities.

Wind Energy Facility	Fatality Estimate	Number of Turbines	Total MW
Thunder Spirit, ND	**1.49**	**43**	**107.5**
Midwest			
Wessington Springs, SD (2009)	8.25	34	51
Blue Sky Green Field, WI (2008; 2009)	7.17	88	145
Cedar Ridge, WI (2009)	6.55	41	67.6
Buffalo Ridge, MN (Phase III; 1999)	5.93	138	103.5
Moraine II, MN (2009)	5.59	33	49.5
Barton I & II, IA (2010-2011)	5.5	80	160
Buffalo Ridge I, SD (2009-2010)	5.06	24	50.4
Buffalo Ridge, MN (Phase I; 1996)	4.14	73	25
Winnebago, IA (2009-2010)	3.88	10	20
Rugby, ND (2010-2011)	3.82	71	149
Cedar Ridge, WI (2010)	3.72	41	68
Elm Creek II, MN (2011-2012)	3.64	62	148.8
Buffalo Ridge, MN (Phase II; 1999)	3.57	143	107.25
Buffalo Ridge, MN (Phase I; 1998)	3.14	73	25
Ripley, Ont (2008)	3.09	38	76
Fowler I, IN (2009)	2.83	162	301
Buffalo Ridge, MN (Phase I; 1997)	2.51	73	25
Buffalo Ridge, MN (Phase II; 1998)	2.47	143	107.25
PrairieWinds SD1, SD (2012-2013)	2.01	108	162
Buffalo Ridge II, SD (2011-2012)	1.99	105	210
Kewaunee County, WI (1999-2001)	1.95	31	20.46
PrairieWinds SD1, SD (2013-2014)	1.66	108	162
NPPD Ainsworth, NE (2006)	1.63	36	20.5
PrairieWinds ND1 (Minot), ND (2011)	1.56	80	115.5
Elm Creek, MN (2009-2010)	1.55	67	100
PrairieWinds ND1 (Minot), ND (2010)	1.48	80	115.5
Buffalo Ridge, MN (Phase I; 1999)	1.43	73	25
PrairieWinds SD1, SD (2011-2012)	1.41	108	162
Top Crop I & II (2012-2013)	1.35	68 phase I; 132 phase II	300 (102 phase I); 198 (phase II)
Heritage Garden I, MI (2012-2014)	1.3	14	28
Wessington Springs, SD (2010)	0.89	34	51
Rail Splitter, IL (2012-2013)	0.84	67	100.5
Top of Iowa, IA (2004)	0.81	89	80
Big Blue, MN (2013)	0.6	18	36
Grand Ridge I, IL (2009-2010)	0.48	66	99
Top of Iowa, IA (2003)	0.42	89	80
Big Blue, MN (2014)	0.37	18	36
Pioneer Prairie II, IA (2011-2012)	0.27	62	102.3

Appendix D1 (*continued*). Fatality estimates (number of bird fatalities per megawatt per year) for all bird species from studies conducted at Midwest wind energy facilities.

Data from the following sources:

Wind Energy Facility	Fatality Estimate	Wind Energy Facility	Fatality Estimate
Wessington Springs, SD (2009)	Derby et al. 2010c	Buffalo Ridge II, SD (2011-2012)	Derby et al. 2012a
Blue Sky Green Field, WI (2008; 2009)	Gruver et al. 2009	Kewaunee County, WI (1999-2001)	Howe et al. 2002
Cedar Ridge, WI (2009)	BHE Environmental 2010	PrairieWinds SD1, SD (2013-2014)	Derby et al. 2014
Buffalo Ridge, MN (Phase III; 1999)	Johnson et al. 2000	NPPD Ainsworth, NE (2006)	Derby et al. 2007
Moraine II, MN (2009)	Derby et al. 2010f	PrairieWinds ND1 (Minot), ND (2011)	Derby et al. 2012d
Barton I & II, IA (2010-2011)	Derby et al. 2011b	Elm Creek, MN (2009-2010)	Derby et al. 2010e
Buffalo Ridge I, SD (2009-2010)	Derby et al. 2010d	PrairieWinds ND1 (Minot), ND (2010)	Derby et al. 2011d
Buffalo Ridge, MN (Phase I; 1996)	Johnson et al. 2000	Buffalo Ridge, MN (Phase I; 1999)	Johnson et al. 2000
Winnebago, IA (2009-2010)	Derby et al. 2010g	PrairieWinds SD1, SD (2011-2012)	Derby et al. 2012c
Rugby, ND (2010-2011)	Derby et al. 2011c	Top Crop I & II (2012-2013)	Good et al. 2013c
Cedar Ridge, WI (2010)	BHE Environmental 2011	Heritage Garden I, MI (2012-2014)	Kerlinger et al. 2014
Elm Creek II, MN (2011-2012)	Derby et al. 2012b	Wessington Springs, SD (2010)	Derby et al. 2011a
Buffalo Ridge, MN (Phase II; 1999)	Johnson et al. 2000	Rail Splitter, IL (2012-2013)	Good et al. 2013b
Buffalo Ridge, MN (Phase I; 1998)	Johnson et al. 2000	Top of Iowa, IA (2004)	Jain 2005
Ripley, Ont (2008)	Jacques Whitford 2009	Big Blue, MN (2013)	Fagen Engineering 2014
Fowler I, IN (2009)	Johnson et al. 2010a	Grand Ridge I, IL (2009-2010)	Derby et al. 2010a
Buffalo Ridge, MN (Phase I; 1997)	Johnson et al. 2000	Top of Iowa, IA (2003)	Jain 2005
Buffalo Ridge, MN (Phase II; 1998)	Johnson et al. 2000	Big Blue, MN (2014)	Fagen Engineering 2015
PrairieWinds SD1, SD (2012-2013)	Derby et al. 2013	Pioneer Prairie II, IA (2011-2012)	Chodachek et al. 2012

Appendix D2. Raptor fatality estimates (number of raptor fatalities per megawatt per year) and raptor use estimates (number of raptors per plot per 20-minute survey) from studies conducted at Midwest wind energy facilities.

Wind Energy Facility	Raptor Use Estimate	Raptor Fatality Estimate	Number of Turbines	Total MW
Thunder Spirit, ND	**0.68**	**0.18**	**43**	**107.5**
	Midwest			
Buffalo Ridge, MN (Phase I; 1999)	NA	0.47	73	25
Moraine II, MN (2009)	NA	0.37	33	49.5
Winnebago, IA (2009-2010)	NA	0.27	10	20
Buffalo Ridge I, SD (2009-2010)	NA	0.2	24	50.4
Cedar Ridge, WI (2009)	NA	0.18	41	67.6
Prairie Winds SD1, SD (2013-2014)	NA	0.17	108	162
Top of Iowa, IA (2004)	NA	0.17	89	80
Cedar Ridge, WI (2010)	NA	0.13	41	68
Ripley, Ont (2008)	NA	0.1	38	76
Wessington Springs, SD (2010)	0.232	0.07	34	51
Rugby, ND (2010-2011)	NA	0.06	71	149
NPPD Ainsworth, NE (2006)	NA	0.06	36	20.5
Wessington Springs, SD (2009)	0.232	0.06	34	51
Prairie Winds ND1 (Minot), ND (2011)	NA	0.05	80	115.5
Prairie Winds ND1 (Minot), ND (2010)	NA	0.05	80	115.5
Prairie Winds SD1, SD (2012-2013)	NA	0.03	108	162
Elm Creek, MN (2009-2010)	NA	0	67	100
Rail Splitter, IL (2012-2013)	NA	0	67	100.5
Pioneer Prairie II, IA (2011-2012)	NA	0	62	102.3
Buffalo Ridge, MN (Phase III; 1999)	NA	0	138	103.5
Buffalo Ridge, MN (Phase II; 1998)	NA	0	143	107.3
Buffalo Ridge, MN (Phase II; 1999)	NA	0	143	107.3
Blue Sky Green Field, WI (2008; 2009)	NA	0	88	145
Elm Creek II, MN (2011-2012)	NA	0	62	148.8
Barton I & II, IA (2010-2011)	NA	0	80	160
Prairie Winds SD1, SD (2011-2012)	NA	0	108	162
Kewaunee County, WI (1999-2001)	NA	0	31	20.5
Buffalo Ridge II, SD (2011-2012)	NA	0	105	210
Buffalo Ridge, MN (Phase I; 1996)	NA	0	73	25
Buffalo Ridge, MN (Phase I; 1997)	NA	0	73	25
Buffalo Ridge, MN (Phase I; 1998)	NA	0	73	25
Fowler I, IN (2009)	NA	0	162	301
Big Blue, MN (2013)	NA	0	18	36
Big Blue, MN (2014)	NA	0	18	36
Top of Iowa, IA (2003)	NA	0	89	80
Grand Ridge I, IL (2009-2010)	0.195	0	66	99

Appendix D2 (*continued*). Raptor fatality estimates (number of raptor fatalities per megawatt per year) and raptor use estimates (number of raptors per plot per 20-minute survey) from studies conducted at Midwest wind energy facilities.

Data from the following sources:

Facility	Use Estimate	Fatality Estimate
Buffalo Ridge, MN (Phase I; 1999)		Johnson et al. 2000
Moraine II, MN (2009)		Derby et al. 2010f
Winnebago, IA (2009-2010)		Derby et al. 2010g
Buffalo Ridge I, SD (2009-2010)		Derby et al. 2010d
Cedar Ridge, WI (2009)		BHE Environmental 2010
Prairie Winds SD1, SD (2013-2014)		Derby et al. 2014
Top of Iowa, IA (2004)		Jain 2005
Cedar Ridge, WI (2010)		BHE Environmental 2011
Ripley, Ont (2008)		Jacques Whitford 2009
Wessington Springs, SD (2010)		Derby et al. 2011a
Rugby, ND (2010-2011)		Derby et al. 2011c
NPPD Ainsworth, NE (2006)		Derby et al. 2007
Wessington Springs, SD (2009)	Derby et al. 2008	Derby et al. 2010c
Prairie Winds ND1 (Minot), ND (2011)		Derby et al. 2012d
Prairie Winds ND1 (Minot), ND (2010)		Derby et al. 2011d
Prairie Winds SD1, SD (2012-2013)		Derby et al. 2013
Elm Creek, MN (2009-2010)		Derby et al. 2010e
Rail Splitter, IL (2012-2013)		Good et al. 2013b
Pioneer Prairie II, IA (2011-2012)		Chodachek et al. 2012
Buffalo Ridge, MN (Phase III; 1999)		Johnson et al. 2000
Buffalo Ridge, MN (Phase II; 1998)		Johnson et al. 2000
Buffalo Ridge, MN (Phase II; 1999)		Johnson et al. 2000
Blue Sky Green Field, WI (2008; 2009)		Gruver et al. 2009
Elm Creek II, MN (2011-2012)		Derby et al. 2012b
Barton I & II, IA (2010-2011)		Derby et al. 2011b
Prairie Winds SD1, SD (2011-2012)		Derby et al. 2012c
Kewaunee County, WI (1999-2001)		Howe et al. 2002
Buffalo Ridge II, SD (2011-2012)		Derby et al. 2012a
Buffalo Ridge, MN (Phase I; 1996)		Johnson et al. 2000
Buffalo Ridge, MN (Phase I; 1997)		Johnson et al. 2000
Buffalo Ridge, MN (Phase I; 1998)		Johnson et al. 2000
Fowler I, IN (2009)		Johnson et al. 2010a
Big Blue, MN (2013)		Fagen Engineering 2014
Big Blue, MN (2014)		Fagen Engineering 2015
Top of Iowa, IA (2003)		Jain 2005
Grand Ridge I, IL (2009-2010)	Derby et al. 2009	Derby et al. 2010a
Buffalo Ridge, MN (Phase III; 1999)		Johnson et al. 2000

Appendix D3. Bat fatality estimates (number of bat fatalities per megawatt (MW) per year) and bat use estimates (number of bat passes per detector-night) from studies conducted at Midwest wind energy facilities.

Wind Energy Facility	Bat Activity Estimate	Bat Activity Dates	Bat Fatality Estimate	Number of Turbines	Total MW
Thunder Spirit, ND	**1.13 (2007) 0.78 (2011)**	**7/23/07-9/6/07 7/23/11-9/02/11**	**12.72**	**43**	**107.5**
	Midwest				
Cedar Ridge, WI (2009)	9.97[A, B, C, D]	7/16/07-9/30/07	30.61	41	67.6
Blue Sky Green Field, WI (2008; 2009)	7.7[D]	7/24/07-10/29/07	24.57	88	145
Cedar Ridge, WI (2010)	9.97[A, B, C, D]	7/16/07-9/30/07	24.12	41	68
Fowler I, II, III, IN (2011)	NA	NA	20.19	355	600
Fowler I, II, III, IN (2010)	NA	NA	18.96	355	600
Forward Energy Center, WI (2008-2010)	6.97	8/5/08-11/08/08	18.17	86	129
Top Crop I & II (2012-2013)	NA	NA	12.55	68 (phase I) 132 (phase (II)	300 (102 (phase I) 198 (phase II))
Rail Splitter, IL (2012-2013)	NA	NA	11.21	67	100.5
Harrow, Ont (2010)	NA	NA	11.13	24 (four 6-turb facilities)	39.6
Top of Iowa, IA (2004)	35.7	5/26/04-9/24/04	10.27	89	80
Fowler I, IN (2009)	NA	NA	8.09	162	301
Crystal Lake II, IA (2009)	NA	NA	7.42	80	200
Top of Iowa, IA (2003)	NA	NA	7.16	89	80
Kewaunee County, WI (1999-2001)	NA	NA	6.45	31	20.46
Heritage Garden I, MI (2012-2014)	NA	NA	5.9	14	28
Ripley, Ont (2008)	NA	NA	4.67	38	76
Winnebago, IA (2009-2010)	NA	NA	4.54	10	20
Pioneer Prairie II, IA (2011-2012)	NA	NA	4.43	62	102.3
Buffalo Ridge, MN (Phase II; 2001/Lake Benton I)	2.2[B]	6/15/01-9/15/01	4.35	143	107.25
Pioneer Prairie II, IA (2013)	NA	NA	3.83	62	102.3
Buffalo Ridge, MN (Phase III; 2001/Lake Benton II)	2.2[B]	6/15/01-9/15/01	3.71	138	103.5
Crescent Ridge, IL (2005-2006)	NA	NA	3.27	33	49.5
Fowler I, II, III, IN (2012)	NA	NA	2.96	355	600
Elm Creek II, MN (2011-2012)	NA	NA	2.81	62	148.8
Buffalo Ridge II, SD (2011-2012)	NA	NA	2.81	105	210
Buffalo Ridge, MN (Phase III; 1999)	NA	NA	2.72	138	103.5
Buffalo Ridge, MN (Phase II; 1999)	NA	NA	2.59	143	107.25
Moraine II, MN (2009)	NA	NA	2.42	33	49.5
Buffalo Ridge, MN (Phase II; 1998)	NA	NA	2.16	143	107.25
PrairieWinds ND1 (Minot), ND (2010)	NA	NA	2.13	80	115.5
Grand Ridge I, IL (2009-2010)	NA	NA	2.1	66	99
Big Blue, MN (2013)	NA	NA	2.04	18	36
Barton I & II, IA (2010-2011)	NA	NA	1.85	80	160
Fowler III, IN (2009)	NA	NA	1.84	60	99
Buffalo Ridge, MN (Phase III; 2002/Lake Benton II)	1.9[B]	6/15/02-9/15/02	1.81	138	103.5
Buffalo Ridge, MN (Phase II; 2002/Lake Benton I)	1.9[B]	6/15/02-9/15/02	1.64	143	107.25

Appendix D3. Bat fatality estimates (number of bat fatalities per megawatt (MW) per year) and bat use estimates (number of bat passes per detector-night) from studies conducted at Midwest wind energy facilities.

Wind Energy Facility	Bat Activity Estimate	Bat Activity Dates	Bat Fatality Estimate	Number of Turbines	Total MW
Rugby, ND (2010-2011)	NA	NA	1.6	71	149
Elm Creek, MN (2009-2010)	NA	NA	1.49	67	100
Wessington Springs, SD (2009)	NA	NA	1.48	34	51
Big Blue, MN (2014)	NA	NA	1.43	18	36
PrairieWinds ND1 (Minot), ND (2011)	NA	NA	1.39	80	115.5
PrairieWinds SD1, SD (2011-2012)	NA	NA	1.23	108	162
NPPD Ainsworth, NE (2006)	NA	NA	1.16	36	20.5
PrairieWinds SD1, SD (2012-2013)	NA	NA	1.05	108	162
Buffalo Ridge, MN (Phase I; 1999)	NA	NA	0.74	73	25
PrairieWinds SD1, SD (2013-2014)	NA	NA	0.52	108	162
Wessington Springs, SD (2010)	NA	NA	0.41	34	51
Buffalo Ridge I, SD (2009-2010)	NA	NA	0.16	24	50.4

A = Activity rate based on data collected at various heights; all other activity rates are from ground-based units only

B = Activity rate was averaged across phases and/or years

C = Activity rate calculated by WEST from data presented in referenced report

D= Activity rate based on pre-construction monitoring; data for all other activity and fatality rates were collected concurrently

Appendix D3. Bat fatality estimates (number of bat fatalities per megawatt (MW) per year) and bat use estimates (number of bat passes per detector-night) from studies conducted at Midwest wind energy facilities.

Data from the following sources:

Facility	Use Estimate	Fatality Estimate	Facility	Use Estimate	Fatality Estimate
Cedar Ridge, WI (2009)	BHE Environmental 2008	BHE Environmental 2010	Buffalo Ridge II, SD (2011-2012)		Derby et al. 2012a
Blue Sky Green Field, WI (08; 09)	Gruver 2008	Gruver et al. 2009	Buffalo Ridge, MN (Phase III; 1999)		Johnson et al. 2000
Cedar Ridge, WI (2010)	BHE Environmental 2008	BHE Environmental 2011	Buffalo Ridge, MN (Phase II; 1999)		Johnson et al. 2000
Fowler I, II, III, IN (2011)		Good et al. 2012	Moraine II, MN (2009)		Derby et al. 2010f
Fowler I, II, III, IN (2010)		Good et al. 2011	Buffalo Ridge, MN (Phase II; 1998)		Johnson et al. 2000
Forward Energy Center, WI (08-10)	Watt and Drake 2011	Grodsky and Drake 2011	PrairieWinds ND1 (Minot), ND (2010)		Derby et al. 2011d
Top Crop I & II (2012-2013)		Good et al. 2013c	Grand Ridge I, IL (2009-2010)		Derby et al. 2010a
Rail Splitter, IL (2012-2013)		Good et al. 2013b	Big Blue, MN (2013)		Fagen Engineering 2014
Harrow, Ont (2010)		NRSI 2011	Barton I & II, IA (2010-2011)		Derby et al. 2011b
Top of Iowa, IA (2004)	Jain 2005	Jain 2005	Fowler III, IN (2009)		Johnson et al. 2010b
Fowler I, IN (2009)		Johnson et al. 2010a	Buffalo Ridge, MN (Phase III; 02/Lake Benton II)	Johnson et al. 2004	Johnson et al. 2004
Crystal Lake II, IA (2009)		Derby et al. 2010b	Buffalo Ridge, MN (Phase II; 01/Lake Benton I)	Johnson et al. 2004	Johnson et al. 2004
Top of Iowa, IA (2003)		Jain 2005	Rugby, ND (2010-2011)		Derby et al. 2011c
Kewaunee County, WI (1999-2001)		Howe et al. 2002	Elm Creek, MN (2009-2010)		Derby et al. 2010e
Heritage Garden I, MI (2012-2014)		Kerlinger et al. 2014	Wessington Springs, SD (2009)		Derby et al. 2010c
Ripley, Ont (2008)		Jacques Whitford 2009	Big Blue, MN (2014)		Fagen Engineering 2015
Winnebago, IA (2009-2010)		Derby et al. 2010g	PrairieWinds ND1 (Minot), ND (2011)		Derby et al. 2012d
Pioneer Prairie II, IA (2011-2012)		Chodachek et al. 2012	PrairieWinds SD1, SD (2011-2012)		Derby et al. 2012c
Buffalo Ridge, MN (Phase II; 2001/Lake Benton I)	Johnson et al. 2004	Johnson et al. 2004	NPPD Ainsworth, NE (2006)		Derby et al. 2007
Pioneer Prairie II, IA (2013)		Chodachek et al. 2014	PrairieWinds SD1, SD (2012-2013)		Derby et al. 2013
Buffalo Ridge, MN (Phase III; 01/Lake Benton II)	Johnson et al. 2004	Johnson et al. 2004	Buffalo Ridge, MN (Phase I; 1999)		Johnson et al. 2000
Crescent Ridge, IL (2005-2006)		Kerlinger et al. 2007	PrairieWinds SD1, SD (2013-2014)		Derby et al. 2014
Fowler I, II, III, IN (2012)		Good et al. 2013a	Wessington Springs, SD (2010)		Derby et al. 2011a
Elm Creek II, MN (2011-2012)		Derby et al. 2012b	Buffalo Ridge I, SD (2009-2010)		Derby et al. 2010d