FINAL REPORT

Bird and Bat Fatality Studies
Fowler Ridge I Wind-Energy Facility
Benton County, Indiana

April 6 – October 30, 2009

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EXECUTIVE SUMMARY

BP Wind Energy North America, Inc. (BPWENA) is developing a wind-energy facility in five separate phases for a total build out capacity of 1,000 megawatts (MW) in Benton County, Indiana. Currently, the first three phases have a total energy capacity of 750 MW. The first phase of the facility, Fowler Ridge I, is jointly owned by BPWENA and Dominion Energy, Inc. and has a nameplate capacity of 301 MW. The Fowler Ridge I Wind–Energy Facility (FRWEF-I) is located approximately 0.5 miles (0.8 km) south and east of Fowler, Indiana, and consists of 122 Vestas V82 1.65-MW turbines and 40 Clipper C96 2.5-MW turbines. BPWENA contracted Western Ecosystems Technology, Inc. (WEST) to conduct a post-construction fatality monitoring study at the Fowler Ridge I facility. The study was designed to assess the level of impacts to birds and bats (i.e., high, moderate, low) relative to other regional projects from operation of the wind-energy facility. Because not all turbines were sampled and because all study plots were not completely cleared of crops, the study was not designed to quantify mortality with a high degree of accuracy for the entire wind energy facility, nor was it designed to detect every wind turbine casualty present on the site. Monitoring at the Fowler Ridge I facility occurred from April 6 to October 30, 2009.

FRWEF-I is located in western Indiana in Benton County. The topography of the site is mostly flat to slightly rolling and there are no hills, ridges, or other areas of starkly elevated topography. Habitat within and surrounding the FRWEF-I is dominated by tilled agriculture, with corn and soybeans being the dominant crops. Of the roughly 29,000 acres (about 43 mi^2) within the FRWEF-I and half-mile (0.8-km) buffer, row crops compose 93%, developed areas compose 5.7%, pastures/hayfields compose 1.7%, grasslands compose 0.1%, and forested areas compose 0.4% of the land cover.

The monitoring study for the FRWEF-I consisted of the following components: 1) standardized carcass surveys of selected turbines within a square plot centered on the turbine; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; 3) carcass removal trials to estimate the length of time that carcasses remain in the field for possible detection; and 4) adjusted fatality estimates based on the results of searcher efficiency trials and carcass removal trials and proportion of the plot searched.

Twenty-five wind turbines were included in the study, and nine of those had crops cleared in late summer within the search plot to facilitate conducting surveys in mature corn and soybean fields. To the extent possible, turbines were selected for sampling using a systematic design with a random start so that the search effort was spread throughout the entire wind-energy facility. However, some modifications to turbine sample selection had to be made to accommodate landowners who did not wish to participate in the study. Square plots 160 by 160 meters (525 by 525 feet) in size were established around the 25 turbines and systematically searched for carcasses. Standardized carcass surveys were conducted anywhere from twice a week to twice a month, with more intensive surveys conducted during the spring and fall migration periods.

Searcher efficiency trials were conducted in the same areas as carcass surveys and searcher efficiency was estimated by the type of carcass (bird or bat), size of carcass (bird carcasses only)

and season. Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by searchers, correcting for detection bias. Carcass removal studies were conducted during each season, outside of the carcass search plots (i.e., near turbines that were not included in the standard search plots). Estimates of carcass removal were used to adjust the total number of carcasses found for those removed from the study plots, correcting for removal bias.

A total of 778 turbine searches were conducted over the course of the fatality monitoring study. Twenty-eight birds and 156 bats were found during standardized carcass surveys or incidentally. Twenty-four birds comprised of 11 identified species were found during scheduled searches, and four additional bird fatalities were found incidentally. The most common bird species found as a casualty at the site was killdeer (four fatalities), followed by tree swallow (three), red-tailed hawk (three) and unidentified large bird (three); two unidentified ducks were also found as fatalities. The three unidentified large birds and two unidentified ducks found during the study consisted entirely of a few large bones with no feathers or flesh remaining. The ducks were identified to type based on skull characteristics, but no skulls were found associated with the remaining three unidentified large birds. The FRWEF-I is near an area designated as an Important Bird Area (IBA) due to high concentrations of staging American golden plovers during spring migration. Although concerns have been raised over the potential for collision mortality, no American golden plover fatalities were found during this study.

Of all the bird fatalities, 35.6% were found within 30 m (99 feet) of the turbine, 28.5% were found from 31 to 60 m (100 to 197 feet), and 35.7% were found more than 60 m from the turbine. Most (64.2%) of the bird fatalities occurred during fall migration (September 3 to October 29), 25.0% occurred during spring migration (April 6 to May 25), and 10.7% occurred during the breeding season (June 10 to August 14).

A total of 107 bat fatalities comprised of six species were found during scheduled searches, and an additional 49 bats were found incidentally. Most (94.2%) of the bat fatalities were migratory tree bats, including 56 eastern red bats (35.9%), 48 hoary bats (30.8%), 42 silver-haired bats (26.9%) and one unidentified *Lasiurus* spp. (either hoary or eastern red bat). The other bat fatalities included four big brown bats, three little brown bats, one northern long-eared bat, and one Indiana bat. The Indiana bat is listed as an endangered species by the US Fish and Wildlife Service. The Indiana bat casualty was collected as an incidental casualty on September 11, 2009. The majority (88.2%) of bat fatalities were found within 40 m (131 feet) of the turbines, and most (73.7%) of the bat fatalities occurred from August 1 to September 15, with an additional 12.8% found between September 16 and October 30.

A total of 89 carcasses (17 large birds, 12 small birds, and 60 bats) were placed in the field during searcher efficiency trials conducted on 11 separate dates. Observer detection rates were 64.3% for large birds, 37.5% for small birds, and 56.0% for bats. A total of 82 carcasses were placed in study area throughout the duration of the monitoring period for carcass removal trials, including 16 large birds, 12 small birds, and 54 bats. By day ten, approximately 30% of the bats remained, while approximately 20% of the large birds and nearly 35% of the small birds remained.

Seven turbines surveyed during the study season were lit with Federal Aviation Administration (FAA) mandated aviation strobe lights and 18 were unlit. There were no significant differences in the number of bird or bat fatalities occurring at turbines with or without FAA lighting.

The estimated fatality rate and 90% confidence interval (CI) for the entire study period (all three study seasons) was 5.26 birds/turbine (90% CI = 3.52, 10.25) and 15.03 bats/turbine (10.89, 20.52). Given the 301-MW nameplate capacity of the FRWEF-I, the overall fatality estimate for the entire study period (all three study seasons) was 2.83 bird fatalities/MW and 8.09 bat fatalities/MW.

The estimated bird fatality rate of 2.83 birds/MW is lower than average compared to other wind-energy facilities in the Midwest. Overall bird fatality estimates at seven Midwest wind-energy facilities located in Nebraska, Wisconsin, Minnesota, Iowa and Illinois have ranged from 0.6 to 7.2 and averaged 4.28 birds/MW/year. The estimated bat fatality rate of 8.09 bats/MW would be considered moderate when compared to other wind-energy facilities in North America, and is somewhat below average based on the regional average for reported bat fatality estimates at seven wind energy facilities in the Midwest, where bat fatality estimates ranged from 0.8 to 30.6, and averaged 9.8 bats/MW/year.

Species composition of bat fatalities was similar to that at most other wind-energy facilities, in that the majority (94.2%) of identified bat fatalities was comprised of three species of migratory tree bats, namely the hoary, eastern red and silver-haired bat. These three species typically comprise over 75% of bat fatalities at wind-energy facilities throughout North America. Based on the timing of fatalities for these three species and the lack of forest cover that might provide habitat for resident bats, most of the fatalities were apparently migrants through the area, as is the case at virtually all other wind energy facilities in North America. It seems unlikely that the FRWEF-I is located along a concentrated tree bat migration route, as there are no topographical features or large expanses of forested areas that would tend to concentrate migrating bats.

Pre-construction ground-based bat acoustical surveys were conducted at the Fowler Ridge Wind Resource Area from August 15 – October 19, 2007 and from July 17 – October 15, 2008, time periods that cover the time frame during which most bat mortality at wind energy facilities occurs throughout North America. Overall bat detections were low to moderate for sites in the Midwest, ranging from 4.7 bat calls/detector-night in 2007 to 6.45 bat calls/detector-night in 2008. Although only 3.2% of the bat casualties found at the FRWEF-I in 2009 were high-frequency species (i.e., *Myotis* spp.), high-frequency bats comprised 49.0% of bat calls in 2007 and 34.2% of bat calls recorded in 2008, suggesting that high frequency species such as *Myotis* bats may be much less susceptible to turbine collisions.

The discovery of an Indiana bat turbine casualty at a wind-energy facility sited in a corn and soybean agroecosystem was unexpected. To our knowledge, this is the first Indiana bat related casualty documented at a wind-energy facility in North America, as well as the first documented casualty of a federally-listed bat species at a wind-energy facility. The Indiana bat casualty found during this study is also apparently the first record of Indiana bat in Benton County, Indiana. Based on the lack of Indiana bat summer habitat at or near the FRWEF-I, and the time frame that the Indiana bat casualty occurred (estimated to be September 9, 2009), this individual was likely a migrant through the area.

To date there have been fewer than 10 studies conducted to estimate bird and bat fatalities from wind turbine operations in the Midwest, and studies at the Fowler Ridge Wind Energy Facility represent the first such studies in Indiana. Results of this study further contribute to our understanding of wind-energy impacts to birds and bats. As more wind-energy facilities are built in the region, and additional studies become available, a clearer picture of the impacts to birds and bats will emerge.

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INTRODUCTION

BP Wind Energy North America, Inc. (BPWENA) is developing a wind-energy facility in five separate phases for a total build out capacity of 1,000 megawatts (MW) in Benton County, Indiana. Currently, the first three phases have a total energy capacity of 750 MW. The first phase of the facility, Fowler Ridge I, jointly owned by BPWENA and Dominion Energy, with a nameplate capacity of 301 MW, is located approximately 0.5 miles (0.8 km) south and east of Fowler, Indiana, and consists of 122 Vestas V82 1.65-MW turbines and 40 Clipper C96 2.5-MW turbines. BPWENA contracted Western Ecosystems Technology, Inc. (WEST) to conduct a post-construction fatality monitoring study at the Fowler Ridge I wind-energy facility to assess the level of impacts to birds and bats (i.e., high, moderate, low) relative to other regional facilities from operation of the Fowler Ridge I Wind-Energy Facility (FRWEF-I). Monitoring at the FRWEF-I occurred from April 6 to October 30, 2009, a time period that covered spring and fall migration as well as the summer breeding season.

The monitoring study for the FRWEF-I consisted of the following components:

1) Standardized carcass surveys of selected turbines within a square plot centered on the turbine;
2) Searcher efficiency trials to estimate the percentage of carcasses found by searchers;
3) Carcass removal trials to estimate the length of time that a carcass remained in the field for possible detection; and
4) Adjusted fatality estimates based on the results of searcher efficiency trials, carcass removal trials, and the proportion of the plot searched.

STUDY AREA

The FRWEF-I is located in western Indiana in Benton County (Figure 1). The project area is within the Tipton Tall Plain physiographic region that includes much of central Indiana. It occurs within the Grand Prairie Natural Region that includes a small section of north central Indiana (Mumford and Whitaker 1982). The topography of the FRWEF-I is mostly flat to slightly rolling and there are no hills, ridges, or other areas of starkly elevated topography. Elevations in the project area range from approximately 700-800 ft (213-244 m). The project area averages 40 inches (102 centimeters [cm]) of precipitation per year and temperatures range from 19 – 45 °F (-7.2 – 7.3 °C) in January to 65 – 86 °F (18 – 30 °C) in July. Soils in the project area are various combinations of silt loam, clay loam, loam, silty clay loam, sandy loams and sandy clays (USDA-NRCS 2006). Much of the area is classified as prime farmland based on soil type. The FRWEF-I is dominated by tilled agriculture, with corn (*Zea mays*) and soybeans (*Glycine max*) being the dominant crops. Of the roughly 29,000 acres (about 43 square miles [mi^2]) of the Fowler Ridge I facility and a half-mile (0.80 km) buffer, row crops compose about 93% of the area (Homer et al. 2004; Table 1; Figure 2). After tilled agriculture, the next most common land use within the FRWEF-I and the buffer is developed areas, which compose 5.7% of the total, and pastures/hayfields, which compose 1.7%. There are 14.8 acres (0.02 mi^2) of grasslands, composing only 0.1% of the study area. Grasslands in the study area are limited primarily to strips along drainages, railroad rights-of-way (ROW), and ROWs along county and state roads. There are also a few grass-lined waterways within cultivated fields in the area. Trees in the study area occur at homesteads, along some of the drainages and fencerows, and in some pastures. Several tree rows planted as wind breaks also occur in the area. Forested areas are rare within the study area based on 2001 data (Homer et al. 2004), and the 118.1 acres (0.18 mi^2) of forest compose only 0.4% of the total. Small amounts of barren ground, open water, and woody wetlands are also present.

METHODS

The primary objective of the monitoring study was to estimate the level (high, moderate, or low) of bird and bat mortality attributable to collisions with wind turbines relative to other regional wind-energy facilities for the entire FRWEF-I. Because not all turbines were sampled and because completely cleared plots were not used for all turbines sampled in the study, the study was not designed to quantify mortality with a high degree of accuracy for the entire wind energy facility, nor was it designed to detect every wind turbine casualty present on the site. The monitoring study began after the wind-energy facility became fully operational. Monitoring began on April 6 and continued through October 30, 2009, to cover the spring and fall migration, as well as the summer breeding season. The methods for the fatality study were broken into four primary components: 1) standardized carcass surveys of selected turbines; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; 3) carcass removal trials to estimate the length of time that a carcass remains in the field for possible detection; and 4) adjusted fatality estimates for bird and bat species calculated using the results from searcher efficiency trials, carcass removal trials, and proportion of the plot searched to estimate the total number of bird and bat fatalities within the FRWEF-I.

There are three scenarios under which casualties were found in the FRWEF-I: 1) during the standardized surveys for the study; 2) while observers were on site, but not conducting a standardized search (i.e., an incidental find); and 3) by facility personnel or others on-site for other purposes, such as turbine maintenance. All casualties found by study personnel regardless of timing (i.e., during a standardized survey or not) were recorded by the methods described below. However, only casualties found on established search plots during scheduled searches were used to estimate total mortality for the wind energy facility.

All bird and bat casualties located within the search areas, regardless of species, were recorded and a cause of death determined, if possible, based on field inspection of the carcass. The total number of bird and bat carcasses was estimated by adjusting for search frequency, removal bias (length of stay in the field), searcher efficiency bias (percent found), and proportion of the survey plot searched. For carcasses where the cause of death was not apparent, the assumption that the casualty was a wind turbine collision casualty was made for the analysis. This approach likely led to an overestimate of the true number of facility-related avian fatalities, but most studies of wind-energy facilities have used this conservative approach because of the relatively high costs associated with obtaining accurate estimates of natural or reference mortality (see Johnson et al. 2000).

Field Methods

The protocol developed for the study suggested that 32 turbines, or 20% of those available, be included in the study. Most of the turbines were placed in corn and soybean fields. Because searcher efficiency in these crop types would be extremely low from early summer until the crops are harvested in late October, the protocol suggested that half (16) of the 32 turbines have crops cleared to facilitate conducting fatality surveys, similar to the methods used to clear crops for searching turbines at the Top of Iowa wind-energy facility in Iowa (Jain 2005). However, due to difficulties with numerous landowners not wishing to participate in the study, or not wanting crops cleared around study turbines, 25 turbines (15.4% of those available) were ultimately included in the study, and nine of those had crops cleared. To the extent possible, turbines were selected for sampling using a systematic design with a random start so that the search effort was spread throughout the entire FRWEF-I. However, some modifications to turbine sample selection had to be made to accommodate landowners who did not wish to participate in the study (Figure 3).

Square plots were established around the 25 turbines and systematically searched for carcasses. Search plots at turbines were 160 m (525 ft) on a side to ensure all areas within 80 m (262 ft) of the turbine were searched. Studies at facilities with other large turbines, such as the Klondike wind-energy facility in Oregon (Johnson et al. 2003b), the Combine Hills facility, also in Oregon (Young et al. 2005), and the Crescent Ridge facility in Illinois (Kerlinger et al. 2007), indicate most of the fatalities are found within the area that is roughly equivalent to the height of the turbine tower.

Prior to when corn and soybean crops began to mature (April 6 to July 3, 2009), the entire 160-m^2 (6.3-acre) plot was searched for all turbines. After July 3, search plots were created by mowing established crops. One of the nine cleared turbines had the entire 160 m^2 search plot cleared of vegetation, whereas in each of the remaining eight turbine plots five strips were cleared of vegetation. Each cleared strip was 500 feet (152-m) long and 10 feet (3 m) wide. One cleared strip was centered vertically on the turbine, and the other four strips were placed horizontally at varying distances from the turbine. Half the turbines had these strips placed 10, 30, 50 and 70 m (33, 98, 164, and 230 ft) from the turbine; the other half had strips placed at 20, 40, 60 and 80 m (66, 131, 197, and 262 ft) from the turbine (see example in Figure 4). This design ensured that all distances from 0 to 80 m away from the turbine were covered during searches. In addition to searching the cleared strips, the portion of the turbine access road within 80 m of the turbine and the turbine pad were also searched. Sixteen of the turbines did not have any crops cleared for searching and the entire 160-m^2 plot was searched from April 6 to August 16, 2009. After August 16, only clear areas, including the turbine pad, access road within 80 m of the turbine, and any other portions of the plot without crops (i.e., areas disturbed by recent construction or flooded areas where crops would not grow), were searched at these turbines because the ability to detect a carcass within the mature corn and soybean fields was greatly reduced. A global positioning system (GPS) was used to measure the total area (cleared strips, turbine pads, access roads, etc.) actually searched at each turbine.

From the start of the study on April 6 through May 21 (spring migration), half of the plots were searched weekly, including the one plot scheduled to have the entire search area cleared, three plots scheduled to have cleared search strips, and eight plots with no scheduled crop clearing. The other half of the plots were searched once every two weeks, including five plots scheduled to have cleared strips and eight plots with no clearing. From May 22 through August 15 (summer), all 25 plots were searched twice a month. Beginning on August 16 and continuing through the end of the study on October 30, all 25 plots were searched twice a week.

Standardized Carcass Surveys

The objective of the standardized carcasses surveys was to systematically search the wind-energy facility for bird and bat casualties that were attributable to collision with project facilities. Study personnel were trained in proper search techniques prior to conducting the carcass surveys.

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

- Intact - a carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
- Scavenged - an entire carcass, which shows signs of being fed upon by a predator or scavenger, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, portion of a carcass, etc.), or a carcass that has been heavily infested by insects.
- Feather Spot - ten or more feathers or two or more primaries at one location indicating a bird fatality had been there.

All carcasses were labeled with a unique number, bagged, and frozen for future reference and possible necropsy. A copy of the data sheet for each carcass was maintained with the bagged and frozen carcass at all times. For all casualties found, data recorded included species, sex and age when possible, date and time collected, GPS location, condition (intact, scavenged, feather spot), and any comments that indicated possible cause of death. All casualties were photographed as found.

Casualties found outside the formal search area were treated following the above protocol as closely as possible. Casualties observed in non-search areas (generally at turbines not included in the study) were coded as incidental discoveries and were documented in a similar fashion as those found during standard searches. Casualties found by wind turbine maintenance personnel and others not conducting the formal searches were similarly documented and included in the overall dataset.

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the percentage of casualties found by searchers. Searcher efficiency trials were conducted in the same areas as carcass surveys and searcher efficiency was estimated by the type of carcass (bird or bat), size of carcass (only bird carcasses) and season. Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by searchers, correcting for detection bias.

Searcher efficiency trials were conducted 11 times throughout the study period. Observers conducting carcass surveys did not know when searcher efficiency trials were being conducted or the location of the trial carcasses. A total of 89 carcasses (17 large birds, 12 small birds, and 60 bats) were placed on 11 dates. Carcasses used for searcher efficiency trials were primarily non-native/non-protected or commercially available species, such as house sparrows (*Passer domesticus*), northern bobwhites (*Colinus virginianus*), ring-necked pheasants (*Phasianus* *colchicus*), and mallards (*Anas platyrhynchos*). The 60 bats used for the trials were all fresh, non-*myotis* species previously found during the study. All searcher efficiency trial carcasses were placed at random locations within the search area prior to that day's scheduled carcass survey. Each trial carcass was discreetly marked (e.g., thread or tape) so that the carcass 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 were 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 Removal Trials

The objective of carcass removal trails was to estimate the average length of time a carcass remained in the study area and was potentially detectable. Carcass removal included removal by predation or scavenging, or removal by other means, such as being plowed into a field. Carcass removal studies were conducted during each season. Estimates of carcass removal were used to adjust the total number of carcasses found for those removed from the study plots, correcting for removal bias.

Trials were spread throughout the study period to incorporate the effects of varying weather, climatic conditions, and scavenger densities. A total of 82 carcasses were placed throughout the duration of the monitoring period (May 1 through October 19, 2009), including 16 large birds, 12 small birds, and 54 bats. Carcass composition was similar to that used for searcher efficiency trials.

Removal trial carcasses were not placed in the standardized search plots in order to minimize the chance of confusing a trial carcass with a turbine casualty. Turbines not included in the standardized carcass surveys were randomly selected for inclusion in the removal trials. Trial carcasses were randomly placed at selected turbines within a plot of similar size to the actual search plots.

Personnel conducting carcass searches monitored the trial birds over a 40-day period, checking the carcasses every day for the first four days of the trial, and then on day 7, day 10, day 14, day 20, day 30, and day 40. This schedule varied somewhat depending on weather and coordination with the other survey work. Removal trial carcasses were marked discreetly (e.g., with dark electrical tape around one or both legs) for recognition by searchers and other personnel, and left at the location until the end of the carcass removal trial. At the end of the 40-day period, any remaining evidence of the carcass was removed.

Search Area

The third factor to be determined in order to adjust the number of fatalities found was the proportion of the turbine plot searched. From April 6 to July 3, the entire 160-m^2 plot was searched at all 25 turbines. After July 3, as crops began to mature, for those nine turbines with cleared crops, the entire 160-m^2 plot was searched at the one turbine that had the entire search plot cleared of crops, whereas only the five cleared search strips, and the bare gravel turbine pads and turbine access road surfaces within 80 m of the turbine were searched at the remaining eight turbines. The total area encompassed by the five cleared search strips in each plot was 2,447.6 m^2. The proportion of area searched decreased as distance from the turbine increased. For example, on average approximately 87% of the area within 10 m of a turbine was searched, whereas only approximately 21% of the area between 71 and 80 m was searched (Figure 5). The distance each casualty was found from the turbine was used to adjust for the search area. For the 16 turbine plots without cleared strips, the entire 160-m^2 plot was searched from April 6 to August 16, at which time the crops had grown to the point that they could no longer be effectively searched. After August 16, only the gravel pad, access road within 80 m of the turbine, and any other areas where visibility was acceptable were searched.

Statistical Methods

Statistical Methods for Fatality Estimates

Estimates of facility-related fatalities were based on:

(1) Observed number of carcasses found during standardized searches during the monitoring period for which the cause of death was either unknown or was probably facility-related;

(2) Non-removal 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 removal trials; and

(3) Searcher efficiency expressed as the proportion of planted carcasses found by searchers during searcher efficiency trials.

Fatality estimates were calculated for all birds, large birds, and bats. The numbers of bird and bat carcasses found incidentally and during scheduled searches were reported. All carcasses located within areas surveyed, regardless of species, were recorded and, if possible, a cause of death was determined based on a cursory field necropsy. Total numbers of bird and bat carcasses were estimated by adjusting for scavenger removal, searcher efficiency, and proportion of the plot searched. If the cause of death was not apparent, a “worst case” presumption was made by attributing the mortality to the operation of the wind-energy facility.

<u>Definition of Variables</u>
The following variables are used in the equations below:

c_i the number of carcasses detected at plot *i* for the study period of interest, for which the cause of death is either unknown or is attributed to the facility

n the number of search plots

k the number of turbines searched

$\bar{c}$ the average number of carcasses observed per turbine per monitoring period

s the number of carcasses used in removal trials

s_c the number of carcasses in removal trials that remain in the study area after 30 days

se standard error (square of the sample variance of the mean)

t_i the time (in days) a carcass remains in the study area before it is removed, as determined by the removal trials

$\bar{t}$ — the average time (in days) a carcass remains in the study area before it is removed, as determined by the removal trials

d — the total number of carcasses placed in searcher efficiency trials

p — the estimated proportion of detectable carcasses found by searchers, as determined by the searcher efficiency trials

I — the average interval between standardized carcass searches, in days

A — proportion of the search area of a turbine actually searched

$\hat{\pi}$ — the estimated probability that a carcass is both available to be found during a search and is found, as determined by the removal trials and the searcher efficiency trials

m — the estimated average number of fatalities per turbine per monitoring period, adjusted for removal and searcher efficiency bias

Observed Number of Carcasses

The estimated average number of carcasses ($\bar{c}$) observed per turbine for the entire monitoring period is:

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

Estimation of Carcass Non-Removal Rates

Estimates of carcass non-removal rates were used to adjust carcass counts for removal bias. Mean carcass removal time ($\bar{t}$) was the average length of time a carcass remained in the study area before it was removed:

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

Estimation of Searcher Efficiency Rates

Searcher efficiency rates were expressed as *p*, the proportion of trial carcasses that were detected by searchers during the searcher efficiency trials. These rates were estimated by carcass size and season.

Estimation of Facility-Related Fatality Rates

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

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

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

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

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

This formula has been independently verified by Shoenfeld (2004). The final reported estimates of *m* and associated standard errors and 90% confidence intervals (CI) were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and CI for complicated test statistics. For each bootstrap sample, $\bar{c}$, $\bar{t}$, p, $\hat{\pi}$, and m were calculated. A total of 5,000 bootstrap samples were used. The reported estimates were the mathematical means of the 5,000 bootstrap estimates. The standard deviation of the bootstrap estimates is the estimated standard error. The lower 5th and upper 95th percentiles of the 5,000 bootstrap estimates are estimates of the lower limit and upper limit of the 90% CI.

RESULTS

Standardized Carcass Surveys

Twenty-five wind turbines were searched over the course of the fatality monitoring study, for a total of 778 turbine searches. Twenty-eight birds and 156 bats were found during standardized carcass surveys or incidentally (Table 2).

Bird Fatalities

Twenty-four birds comprised of 11 identified species were found during scheduled searches (Table 2 and Figure 6), and four additional bird fatalities were found incidentally. The most common bird species found as a casualty at the site was killdeer (*Charadrius vociferus*; four fatalities), followed by tree swallow (*Tachycineta bicolor*; three), red-tailed hawk (*Buteo jamaicensis*; three) and unidentified large bird (three); two unidentified ducks were also found. The three unidentified large birds and the two unidentified ducks found during the study consisted entirely of a few large bones with no feathers or flesh remaining. The ducks were identified to type based on skull characteristics, but no skulls were found associated with the three unidentified large birds.

The greatest number of bird fatalities found at any one turbine was six at Turbine 629 (Figure 7). These included one blue-winged teal (*Anas discors*), two unidentified ducks, and one unidentified large bird found during the initial phases of the study (April 10 to May 6, 2009).). Turbine 629 had a large pool of water (approximately 200-m [656-ft] long by 30-m [98-ft] wide) within the search plot, which may have attracted waterfowl. None of the other turbines had persistent water present during surveys. Turbine 152 had three fatalities, whereas all other search turbines had none, one, or two fatalities (Figure 7). No bird fatalities were found at Turbine 249, which had the entire search plot cleared of vegetation. With the exception of Turbine 629, bird mortality did not appear to be concentrated within any portion of the study area. Of the bird fatalities, 35.6% were found within 30 m of the turbine, 28.5% were found from 31-60 m, and 35.7% were found beyond 60 m of the turbine (Table 3 and Figure 8). Most (64.2%) of the bird fatalities occurred during fall migration (September 3 to October 29), 25.0% occurred during spring migration (April 6 to May 25), and 10.7% occurred during the breeding season (June 10 to August 14; Figure 9). Of the bird fatalities, 39.3% were intact, 39.3% were scavenged, and 21.4% were feather spots (Appendix A).

Bat Fatalities

A total of 107 bat fatalities comprised of six species were found during scheduled searches and an additional 49 bats were found incidentally (Table 2; Figure 10). Most (94.2%) of the fatalities were migratory tree bats, including 56 eastern red bats (*Lasiurus borealis*; 35.9%), 48 hoary bats (*Lasiurus cinereus*; 30.8%), 42 silver-haired bats (*Lasionycteris noctivagans*; 26.9%) and one unidentified *Lasiurus* spp. (either hoary or eastern red bat). The other bat fatalities included four big brown bats (*Eptisecus fuscus*), three little brown bats (*Myotis lucifugus*), one northern long-eared bat (*Myotis septentrionalis*), and one Indiana bat (*Myotis sodalis*).

The Indiana bat is listed as an endangered species by the US Fish and Wildlife Service (USFWS; USFWS 2010). The casualty was found by a BPWENA turbine maintenance worker and reported to WEST on September 10, 2009. WEST collected the bat as an incidental casualty on September 11, 2009. It was located 16 m (52 feet) from Turbine 230 (Figure 10). The carcass was a female and was intact. Although it was slightly decomposed, the bat was estimated to have been killed the night prior to when it was first discovered, or on September 9, 2009. The bat was stored in a WEST freezer until being tentatively identified as an Indiana bat on November 13, 2009 while a WEST field biologist was reviewing all bird and bat casualties at the end of the field study to confirm identifications. The identification was confirmed by Jeremy Jackson with Jackson Environmental on November 16, 2009. On November 17, 2009, voicemail messages were left notifying both the USFWS and IDNR of the Indiana bat casualty. On November 18, 2009, both the USFWS and IDNR returned the previous call and were notified of the potential Indiana bat find. On November 18, 2009, WEST sent a skin sample from the bat for DNA testing to Portland State University, and the bat was transferred on November 19, 2009 to Mike Litwin of the USFWS. On December 12, 2009, the DNA lab notified WEST that the specimen was positive for Indiana bat; this information was then relayed to the USFWS and IDNR on December 28, 2009. The USFWS conducted a necropsy of the bat carcass, which found that due to desiccation of the limbs it could not be determined whether the identified fractures of the ribs, right clavicle, left wing and left mandible occurred after the bat had died or were the result of injuries sustained at the time of death.

The greatest number of bat fatalities found at any one turbine was 18 fatalities at Turbine 606. Thirteen fatalities were found at Turbine 265, while fatalities at other turbines ranged from none to nine (Figure 11). Six bat fatalities were found at Turbine 249, which had the entire search plot cleared of vegetation. The majority of bat fatalities (88.2%) were found within 40 m of the turbines (Table 3 and Figure 12). Most (73.7%) of the bat fatalities occurred from August 1 to September 15 (Figure 13). An additional 12.8% were found between September 16 and October

30; therefore, 86.5% of all fatalities were found from August 1 to October 30. Thirteen bat fatalities were found between April 6 and May 25, and only eight were found in June and July. Most (85.8%) of the bat fatalities were intact while 14.2% were scavenged (Appendix A).

Searcher Efficiency Trials

A total of 89 carcasses (17 large birds, 12 small birds, and 60 bats) were placed in the field during searcher efficiency trials conducted on 11 separate dates (Table 4). Observer detection rates were 64.3% for large birds, 37.5% for small birds, and 56.0% for bats (Table 4).

Carcass Removal Trials

A total of 82 carcasses were placed in study area throughout the duration of the monitoring period, including 16 large birds, 12 small birds, and 54 bats. By day ten, approximately 30% of the bats remained, while approximately 20% of the large birds and nearly 35% of the small birds remained (Figure 14).

For weekly searches, approximately 92.5% of the bat and 58.8% of the bird fatalities were estimated to have been killed within the previous seven days (Table 5). For biweekly searches, it was estimated that 96.4% of the bat and 62.5% of the bird fatalities had been present less than a week (Table 5).

Adjusted Fatality Estimates

Fatality estimates, standard errors, and CI were calculated for birds and bats (Appendices B and C). The fatality estimates were adjusted based on the corrections for carcass removal, observer detection bias, and the proportion of the plot searched. Based on searcher efficiency and the carcass removal rate at the site, the estimated average probability for all search intervals that a casualty would remain in the plot until a scheduled search and would be found was 51% for small birds, 62% for large birds, and 56% for bats (Table 6).

Because all three raptors found during the study were found as incidental fatalities and not during standardized searches, separate fatality estimate for raptors could not be calculated. The estimated fatality rate and 90% CI for the entire study period (all three study seasons) was 5.26 birds/turbine (3.52, 10.25) and 15.03 bats/turbine (10.89, 20.52; Table 6). Given the 1.65 and 2.5-MW capacity of turbines at the FRWEF-I, the overall fatality estimate for the entire study period was 2.83 bird fatalities/MW and 8.09 bat fatalities/MW. Given that the project is 301 MW in size, the estimated number of fatalities during the study period for the entire facility was 852 birds and 2,435 bats.

Lighting Effects and Turbine Location Effects

Seven turbines surveyed during the study season were lit with mandated Federal Aviation Administration (FAA) aviation strobe lights and 18 were unlit. Not including incidental finds, four bird carcasses were found at lit turbines (0.57 fatalities/turbine), compared to 21 at unlit turbines (1.17 fatalities/turbine; Table 7). The difference in means between lit and unlit turbines was -0.59 with a 90% CI of -1.65 to 0.46 (Table 7). Because the 90% CI included the value 0, this indicates that presence of turbine lighting had no effect on bird fatality rates.

Not including incidental finds, 39 bat carcasses were found at lit turbines (5.57 fatalities/turbine) and 73 were found at unlit turbines (4.06 fatalities/turbine). The difference of means between lit and unlit turbines was 1.52 with a 90% CI of -1.77 to 4.80 (Table 7), again indicating that turbine lighting had no effect on bat fatality rates.

DISCUSSION

Fatality Estimates

The approach used for calculating adjusted fatality estimates is consistent with the approach outlined by Shoenfeld (2004) and Erickson (2006), and accounted for search interval, total area searched, proportion of area searched at specific distances from the turbine, searcher efficiency rates, and carcass removal rates. It is hypothesized that scavenging could change through time at a given site and must be accounted for when attempting to estimate fatality rates. We accounted for this by conducting scavenging trials throughout the monitoring period. We also estimated searcher efficiency rates throughout the study period to account for any biases associated with changes in conditions.

We calculated separate estimates of bird and bat fatality rates based on search interval. For both birds and bats, overlapping CI for overall fatality estimates based on weekly and biweekly search intervals (Tables 6 and 7) indicate that the estimates were consistent regardless of search interval. However, given the estimated scavenging rates of birds and bats, the weekly estimates are likely more reliable.

There are numerous factors that could contribute to both positive and negative biases in estimating fatality rates (Erickson 2006). The design of this study incorporated several assumptions or factors that may affect the results of the fatality estimates. It was assumed that all carcasses found during this study were due to collision with wind turbines; however, the true cause of death is unknown for most of the bird fatalities. It is possible that some of the bird fatalities were caused by predators, and some of the casualties included in the data pool were potentially due to natural causes (background mortality). In contrast, it is unlikely that any of the bat fatalities were due to factors not related to interactions with wind turbines.

There are some other potential negative biases. For example, no adjustments were made for fatalities possibly occurring outside of the square plot boundaries, which were established a minimum distance of 80 m from the turbines. The search plot distance for this study was selected based on results of other studies (Higgins et al. 1996; Johnson et al. 2002, 2003a, 2004; Erickson et al. 2004; Young et al. 2003b, 2005; Kerlinger et al. 2007) in which a distance equal to the approximate height of the turbine hub appeared to capture the vast majority of fatalities. Based on the distribution of fatalities as a function of distance from turbines (Figures 8 and 12), a small percentage of bird and bat fatalities possibly fell outside the search plots and may have been missed. This factor would lead to an underestimate of fatality rates.

Other potential biases are associated with the experimental carcasses used in searcher efficiency and carcass removal trials in terms of whether or not they are representative of actual turbine fatalities. If the types of birds used are larger or smaller than turbine fatalities, or more or less cryptic in color than actual fatalities, then the potential for biased estimates increases. House sparrows, northern bobwhites, ring-necked pheasants, and mallards were used to represent the range of bird fatalities expected. It is believed that this range of species and sizes of birds captured the range of sizes and other characteristics of actual fatalities and should result in reasonable estimates of scavenging rates and searcher efficiency for birds as a group. Because we used fresh bat carcasses found during the study for searcher efficiency and scavenger removal studies, no biases should be associated with these data for the species most commonly found (eastern red, hoary and silver-haired bats). However, because *Myotis* bats are smaller and more cryptically colored than the tree bats, searcher efficiency rates may be lower than estimated for *Myotis* bats, although bats in this genus comprised only a minor amount (3.2%) of the fatalities.

Concern has also been raised regarding how the number of carcasses placed in the field for carcass removal trials on a given day could lead to biased estimates of scavenging rates. Hypothetically, this would lead to underestimating true scavenging rates if the scavenger densities are low enough such that scavenging rates for the placed carcasses are lower than for actual fatalities. The logic is that if the trials are based on too many carcasses on a given day, scavengers are unable to access all trial carcasses, whereas they could access all wind turbine collisions. If this is the case, and the trial carcass density is much greater than actual turbine casualty density, the trials would underestimate scavenging rates compared to scavenging rates of actual fatalities. In this study, 82 carcasses were placed for scavenger trials during the study period and we believe this was not a high enough density to create a significant bias.

Bird Fatalities

The estimated overall bird fatality rate of 2.83 birds/MW is below average compared to other wind-energy facilities in the Midwest (Figure 15). The range of overall bird fatality estimates for 48 studies at wind-energy facilities across North America ranged from no fatalities to 13.93 birds/MW/year. Compared to these other facilities, the FRWEF-I ranked 17th (Figure 15). Overall bird fatality estimates at seven Midwest wind-energy facilities located in Nebraska, Wisconsin, Minnesota, Iowa, and Illinois (BHE Environmental, Inc. 2010, Derby et al. 2007; Gruver et al. 2009; Howe et al. 2002; Johnson et al. 2000, 2002; Jain 2005; Kerlinger et al. 2007) have ranged from 0.6 to 7.2, and averaged 4.28 birds/MW/year (Figure 15).

The FRWEF-I is near an area designated as an Important Bird Area (IBA) due to high concentrations of staging American golden plovers (*Pluvialis dominica*) during spring migration. Although concerns have been raised over the potential for collision mortality, no American golden plover fatalities were found during this study. No species of birds found as fatalities at the FRWEF-I are state or federally listed species, and all are relatively common birds in Indiana. Based on the relatively small estimate of per-turbine avian mortality at the FRWEF-I, and the fact that this mortality occurred throughout the year and did not disproportionately affect any one species, it is unlikely that operation of this facility will result in any significant impacts to bird populations, as has been the case at other operating wind-energy facilities in North America (Johnson and Stephens 2010).

Bat Fatalities

The estimated bat fatality rate at FRWEF-I of 8.09 bats/MW/year would be considered moderate when compared to other wind-energy facilities in North America (Figure 16), and is somewhat below average based on the regional average for reported bat fatality estimates at wind-energy facilities in the Midwest. Bat fatality estimates from 48 studies at other wind-energy facilities across North America ranged from none to 39.7 fatalities/MW/year. Compared to these other facilities, the FRWEF-I ranked 16th (Figure 16). At seven other wind-energy facilities in the Midwest (BHE Environmental Inc. 2010, Derby et al. 2007; Gruver et al. 2009; Howe et al. 2002; Johnson et al. 2003, 2004; Jain 2005; Kerlinger et al. 2007), bat fatality estimates ranged from 0.8 to 30.6, and averaged 9.8 fatalities/MW/year (Figure 16). With the exception of two facilities in Wisconsin (both of which were also located in a corn and soybean agroecosystem), where estimated bat mortality was 24.6/MW/year (Gruver et al. 2009) and 30.6/MW/year (BHE Environmental, Inc. 2010), the highest fatality estimates for bats have come from the eastern US, particularly the Appalachian region where estimates have ranged from 15.7 to 39.7 bats/MW/year (Arnett et al. 2008).

Six of the seven fatality monitoring studies from the Midwest were conducted primarily in a matrix of corn and soybeans, similar to conditions at the FRWEF-I. However, only BHE Environmental Inc. (2010), Jain (2005) and Gruver et al. (2009) attempted to maintain a portion of the search plots in a low- or no-vegetative condition as we did in this study. During the growing season, searching in un-mowed crop fields becomes progressively more physically difficult, and progressively less effective from a searcher efficiency standpoint. Thus the most ready comparison of results from the FRWEF-I, based on similarity of methods and habitat, is to the Top of Iowa wind-energy facility in north-central Iowa (Jain 2005), the Blue Sky Greenfield facility in Wisconsin (Gruver et al. 2009), and the Cedar Ridge wind project in Wisconsin (BHE Environmental, Inc. 2010). Interestingly, Jain (2005), Gruver et al. (2009), BHE Environmental, Inc. (2010) and this study reported higher numbers of fatalities than any of the other studies conducted in the Midwest that did not clear crops for searching.

Pre-construction ground-based bat acoustical surveys were conducted at the Fowler Ridge Wind Resource Area from August 15 – October 19, 2007 (Gruver et al. 2007) and from July 17 – October 15, 2008 (Carder et al. 2009), time periods that cover the time frame during which most bat mortality at wind energy facilities occurs throughout North America. Overall bat detections were low to moderate for sites in the Midwest, ranging from 4.7 bat calls/detector night in 2007 to 6.45 bat calls/detector night in 2008. Although only 3.2% of the bat casualties found at the FRWEF-I in 2009 were high-frequency species (i.e., *Myotis* spp.), high-frequency bats comprised 49.0% of bat calls in 2007 and 34.2% of bat calls recorded in 2008, suggesting that high frequency species such as *Myotis* bats may be much less susceptible to turbine collisions.

Landscape and habitat context have both been proposed as hypotheses to explain bat fatalities at wind-energy facilities. For example, in the eastern US, clearings cut into the forested ridges on which some wind-energy facilities are built are thought to contribute to the relatively high numbers of bat fatalities at these sites, as clearings create potential foraging habitat, and ridges may serve as attractive linear features during foraging, commuting, or migration (Kunz et al. 2007). None of those features are present at the FRWEF-I. However, the relatively large numbers of bat fatalities reported in Wisconsin (BHE Environmental, Inc. 2010, Gruver et al. 2009), Iowa (Jain 2005), and southwestern Alberta (Baerwald 2006) indicate that an open landscape is no guarantee of low mortality.

Species composition of bat fatalities at the FRWEF-I was similar to that at most other wind-energy facilities, in that the majority (94.2%) of bat fatalities was composed of three migratory tree bat species, namely the hoary, eastern red, and silver-haired bat. These three species typically compose over 75% of bat fatalities at wind-energy facilities throughout North America (Johnson 2005, Arnett et al. 2008). Based on the timing of fatalities for these three species and the lack of forest cover that might provide summer habitat for bats, most of the fatalities were apparently migrants through the FRWEF-I, as is the case at virtually all other wind-energy facilities in North America (Johnson 2005, Arnett et al. 2008). Although it is known that most bat mortality occurs during fall migration, it is not known if migrating bats are particularly susceptible, or if other aspects of their behavior, such as mating or feeding behavior, change during the fall and therefore make bats more susceptible to turbine collisions whether they are migrating or not (Cryan and Barclay 2009).

It seems unlikely that the FRWEF-I is located along a concentrated tree bat migration route, as there are no topographical features or large expanses of forested areas that would tend to concentrate migrating bats. However, for hibernating bats, such as *Myotis* spp., migration routes between summer areas and hibernacula may be present regardless of the habitat and topography. This study was not designed to address that question, and obtaining information on migratory routes by bats (assuming they exist) has proven to be very difficult to date (Arnett et al. 2008). However, Baerwald and Barclay (2009) monitored bat activity in the fall at seven proposed or existing wind-energy facilities across southern Alberta and found that activity of migratory bats varied among the sites, suggesting that migrating bats may concentrate along certain routes rather than migrate in a dispersed fashion across a broad area.

Because migratory tree bats are primarily solitary tree dwellers that do not hibernate, it has not been possible to develop any suitable field methods to estimate their population sizes. As a result, impacts on these bat species caused by wind energy development cannot be put into perspective from a population impact standpoint. To help solve this problem, population genetic analyses of DNA sequence and microsatellite data are being conducted to provide effective population size estimates, to determine if populations are growing or declining, and to see if these populations are comprised of one large population or several discrete subpopulations that use spatially segregated migration routes (Dr. Amy L. Russell, Assistant Professor, Grand Valley State University, Allendale, Michigan, pers. comm.). To date, initial analyses have been conducted only for eastern red bat using mitochondrial DNA. Based on these analyses, it appears that this species fits a model of a single, very large population with a history of strong population growth (Vonhof and Russell in prep). The data do not suggest there are multiple populations separated by distinct migratory corridors. Although the point estimate for the eastern red bat population size in North America is 3.3 million, according to Dr. Russell (pers. comm.), the true population size is likely “millions to tens of millions” in size.

Additional research will be required to determine what impact wind-energy facilities have on migratory tree bat populations. Specifically, population size estimates similar to those available for eastern red bat need to be determined for hoary bat and silver-haired bat.

The discovery of an Indiana bat turbine casualty at a wind-energy facility located in a corn and soybean agroecosystem was unexpected. To our knowledge, this is the first Indiana bat turbine collision related casualty documented in North America, as well as the first documented casualty of a federally-listed bat species. As recommended by the USFWS draft interim guidelines for wind-energy development (USFWS 2003), the FRWEF-I was sited in a highly altered landscape, as tilled agriculture composes 93% of the study area. BPWENA commissioned a Site Characterization Study (SCS) to characterize environmental issues associated with construction of a wind-energy facility within the Fowler Ridge Wind Resource Area (FRWRA; Johnson and Poulton 2007). The SCS addressed the potential for impacts to Indiana bat based on literature and database searches, contacts with the Indiana Department of Natural Resources (IDNR) and the USFWS, habitat mapping, and a site visit. At the time the SCS was prepared in 2007, there were no records of Indiana bat in Benton County. Therefore, the casualty found during this study is likely the first documented occurrence of Indiana bat in Benton County. Based on the lack of forest cover in and surrounding the project area (<1%), and evidence that Indiana bat breeding records in Indiana occur primarily in the southern half of the state (Mumford and Whitaker 1982), the SCS concluded that the Indiana bat is not likely to occur within the FRWRA during the summer. In addition, there are no known Indiana bat hibernacula near the project area; the closest is in Greene County, Indiana, approximately 100 miles (161 km) south of the FRWEF-I. The SCS also concluded that even if resident Indiana bats were to occur in the region, the risk of turbine collisions was considered low because: 1) foraging Indiana bats select for forested habitats and riparian areas and against agricultural and grassland habitats in relation to habitat availability (Menzel et al. 2005); 2) in Indiana, Indiana bats forage primarily along wooded riparian areas and forest edges, with no foraging being documented in open pastures, cornfields, upland hedgerows, or along creeks where trees had been removed (Humphrey et al. 1977); and 3) foraging by Indiana bats was confined to air space from 2 to 30 m (6 to 98 ft) high (Humphrey et al. 1977), which is below the rotor-swept area of modern wind turbines proposed for the project. The USFWS conducted a desktop review of aerial photographs, topographic maps, and other information, and also concluded that there does not appear to be much suitable summer bat habitat within the project area (letter dated October 13, 2006 to Ms. Victoria Poulton, WEST, Inc., from Michael Litwin, USFWS).

Although the SCS concluded that impacts to summer populations of Indiana bats were not likely, the SCS did state that because the FRWRA is within the range of Indiana bat, some potential existed for Indiana bats to migrate through the proposed wind resource area between summer ranges and winter hibernacula. The SCS further stated that any wind-energy facility located in the 25 US states within the potential range of the Indiana bat had some potential for collisions of migrating Indiana bats. Based on the lack of summer habitat at or near the FRWEF-I, and the time frame that the Indiana bat casualty occurred (September 09, 2009), this individual was likely a migrant through the area.

To date there have been fewer than 10 studies conducted to estimate bird and bat fatalities from wind turbine operations in the Midwest, and studies at the Fowler Ridge Wind Energy Facility represent the first such studies in Indiana. Results of this study further contribute to our understanding of wind-energy impacts to birds and bats. As more wind-energy facilities are built in the region, and additional studies become available, a clearer picture of the impacts to birds and bats will emerge.

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Table 1. Landcover classification at the Fowler Ridge I Wind-Energy Facility in Benton County, Indiana (from Homer et al. 2004).

Land Cover	Acres	% Composition
Open Water	15.77	0.1
Developed, Open Space	648.33	2.2
Developed, Low Intensity	967.62	3.3
Developed, Medium Intensity	36.68	0.1
Developed, High Intensity	14.81	0.1
Barren	10.02	<0.1
Deciduous Forest	118.09	0.4
Grassland	14.79	0.1
Pasture/Hay	494.40	1.7
Crops	26,692.40	92.90
Woody Wetlands	1.23	<0.1
Total	**29,014.15**	**100**

Table 2. Total number of bird and bat casualties and the composition of casualties discovered at the Fowler Ridge I Wind-Energy Facility from April 6 – October 30, 2009.

	Scheduled Searches		Total	
Species	**Total**	**% Composition**	**Total**	**% Composition**
Birds				
killdeer	4	16.7	4	14.3
tree swallow	3	12.5	3	10.7
unidentified large bird	3	12.5	3	10.7
red-tailed hawk	0	0.0	3	10.7
Tennessee warbler	2	8.3	2	7.1
unidentified duck	2	8.3	2	7.1
blue-winged teal	1	4.2	1	3.6
brown-headed cowbird	1	4.2	1	3.6
green-winged teal	1	4.2	1	3.6
horned lark	1	4.2	1	3.6
house wren	1	4.2	1	3.6
mourning dove	1	4.2	1	3.6
red-eyed vireo	1	4.2	1	3.6
unidentified bird	1	4.2	1	3.6
unidentified passerine	1	4.2	1	3.6
yellow-rumped warbler	1	4.2	1	3.6
American robin	0	0.0	1	3.6
Overall	**24**	**100**	**28**	**100**
Bats				
eastern red bat	43	40.2	56	35.9
silver-haired bat	30	28.0	42	26.9
hoary bat	29	27.1	48	30.8
big brown bat	2	1.9	4	2.6
little brown bat	2	1.9	3	1.9
northern long-eared bat	1	0.9	1	0.6
Indiana bat	0	0.0	1	0.6
unid. *Lasiurus* bat	0	0.0	1	0.6
Overall	**107**	**100**	**156**	**100**

Table 3. Distribution of distances of bird and bat casualties from turbines at the Fowler Ridge I Wind-Energy Facility.

Distance to Turbine (m)	% Bird Casualties	% Bat Casualties
0 – 10	7.1	29.4
11 – 20	7.1	24.2
21 – 30	21.4	19.6
31 – 40	7.1	15.0
41 – 50	10.7	3.9
51 – 60	10.7	3.9
>60	35.7	3.9

Table 4. Searcher efficiency results at the Fowler Ridge I Wind-Energy Facility as a function of season and carcass size.

Size	Date	# Placed	# Available	# Found	% Found
Large Birds	4/30/2009	4	2	1	50.0
	5/27/2009	4	4	4	100.0
	6/26/2009	4	4	3	75.0
	7/21/2009	4	4	1	25.0
	8/4/2009	1	0	0	0
	Overall	**17**	**14**	**9**	**64.3**
Small Birds	4/30/2009	4	2	2	100.0
	5/27/2009	4	4	1	25.0
	7/21/2009	4	2	0	0
	Overall	**12**	**8**	**3**	**37.5**
Bats	6/26/2009	4	2	1	50.0
	8/4/2009	7	4	3	75.0
	8/25/2009	7	5	1	20.0
	9/8/2009	8	7	3	42.9
	9/14/2009	8	7	2	28.6
	9/28/2009	10	10	8	80.0
	10/6/2009	8	7	5	71.4
	10/19/2009	8	8	5	62.5
	Overall	**60**	**50**	**28**	**56.0**

Table 5. Estimated time since death of bird and bat carcasses for weekly and bi-weekly search schedules.

Species	Estimated Time	% Found During Bi-Weekly Searches	% Found During Weekly Searches
Birds	last night	0	5.9
	2-3 days	12.5	35.3
	4-7 days	50.0	17.6
	7-14 days	0	5.9
	>2 weeks	0	0
	> month	0	29.4
	unknown	37.5	5.9
Bats	last night	35.7	37.0
	2-3 days	41.1	29.6
	4-7 days	19.6	25.9
	7-14 days	1.8	1.9
	>2 weeks	0	1.85
	> month	0	0
	unknown	1.8	3.7

Table 6. Bird and bat average probability of carcass availability and detection and overall bird and bat mortality estimates for the Fowler Ridge I Wind-Energy Facility.

Size	Avg. Probability of Carcass Availability and Detection with 90% Confidence Interval
Small Birds	0.51 (0.21 – 0.71)
Large Birds	0.62 (0.42 – 0.79)
Bats	0.56 (0.45 – 0.66)
Species	**Fatalities/turbines/study period**
All Birds	5.26 (3.52 – 10.25)
Bats	15.03 (10.89 – 20.52)

Table 7. Average number of bird and bat carcasses found at turbines lit with FAA aviation strobe lights compared to those at unlit turbines at the Fowler Ridge I Wind-Energy Facility.

Species		Lit Turbines	Unlit Turbines	Overall
Birds	# of Turbines	7	18	25
	# of Fatalities	4	21	25
	Mean # of Fatalities	0.57	1.17	n/a
	Difference of Means	-0.60		n/a
	Confidence Interval	-1.65 – 0.46		n/a
Bats	# of Turbines	7	18	25
	# of Fatalities	39	73	112
	Mean # of Fatalities	5.57	4.06	n/a
	Difference of Means	1.52		n/a
	Confidence Interval	-1.77 – 4.80		n/a

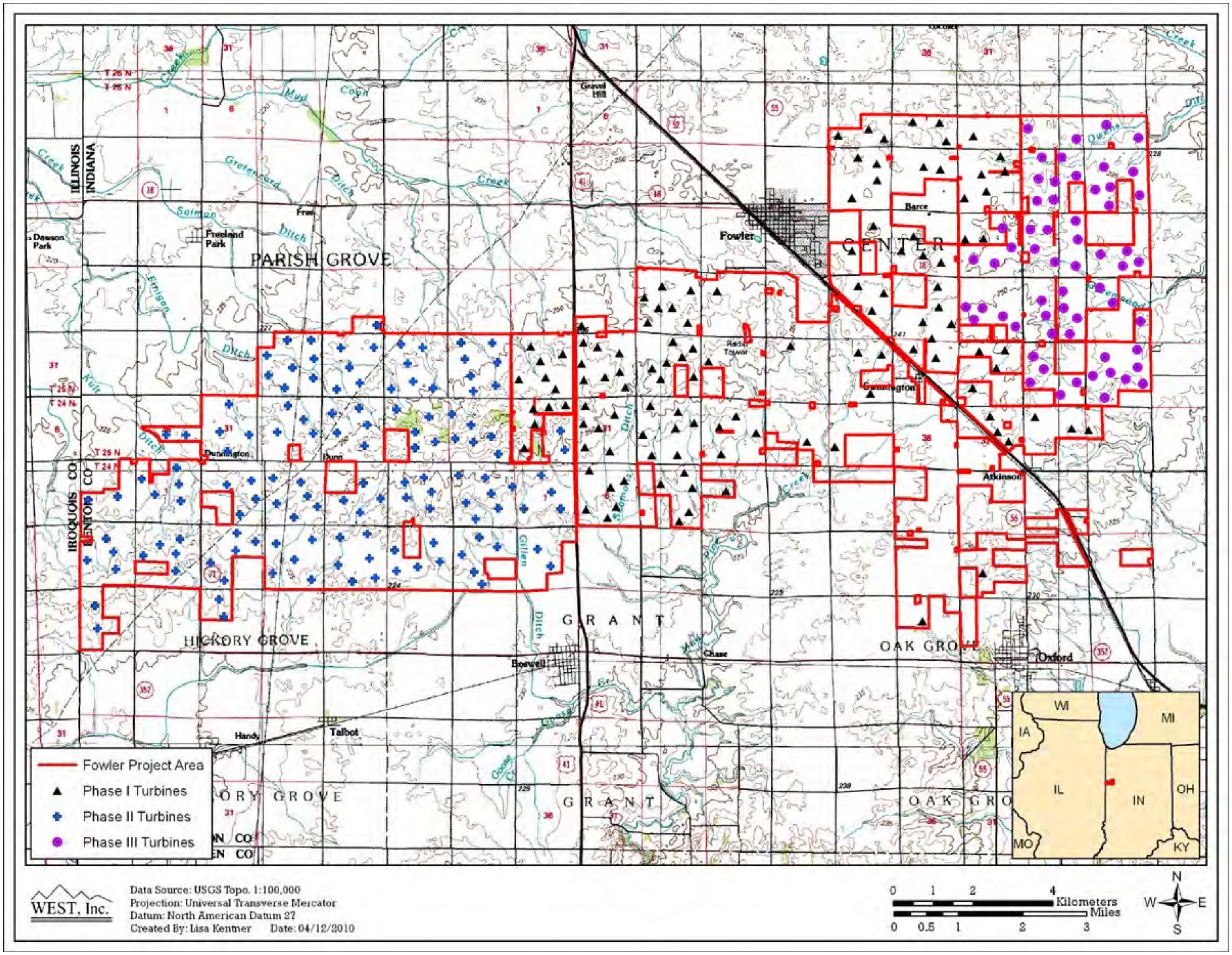

Figure 1. Location of the Fowler Ridge Wind-Energy Facility in Benton County, Indiana.

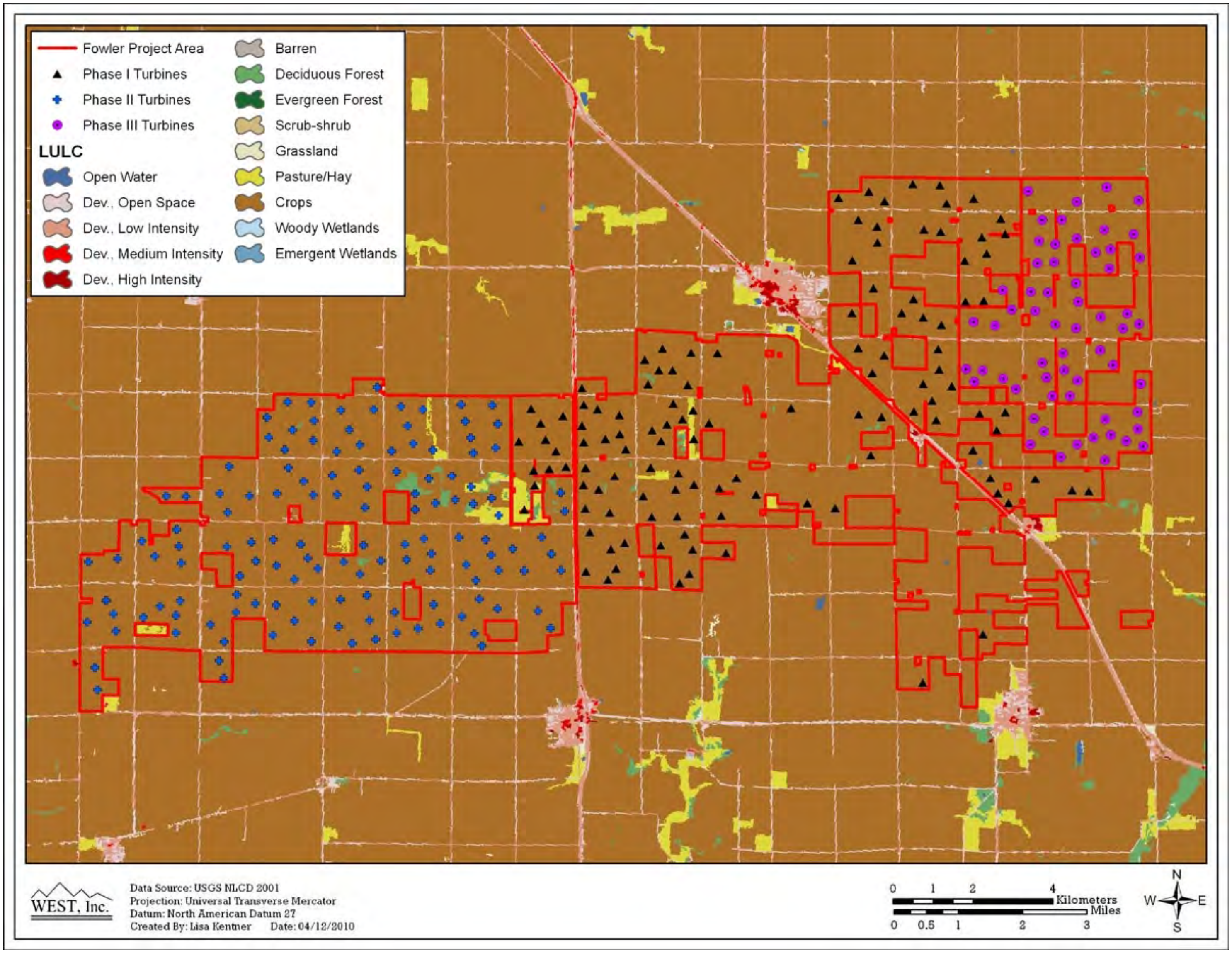

Figure 2. Landcover types at the Fowler Ridge I Wind-Energy Facility.

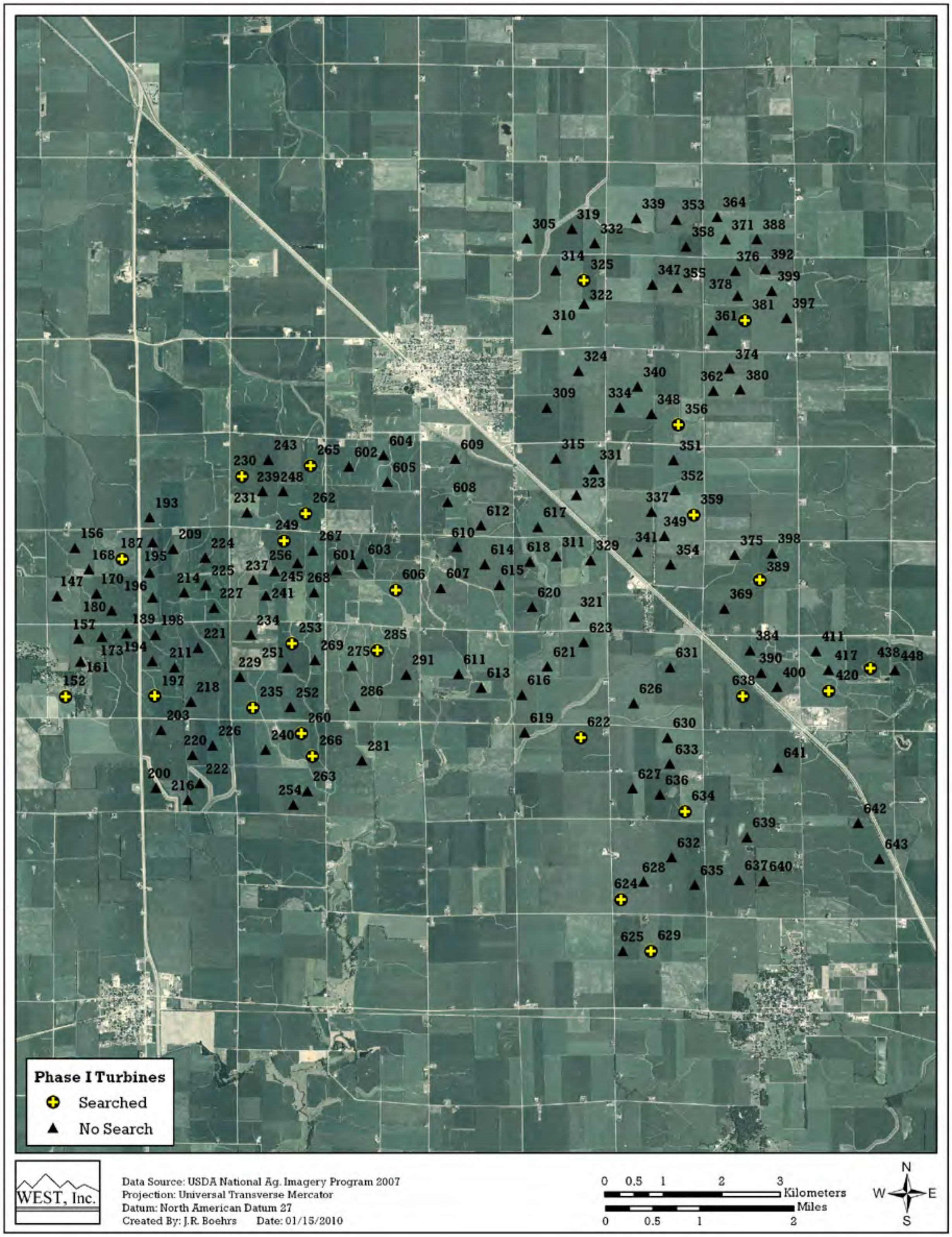

Figure 3. Location of carcass search plots at the Fowler Ridge I Wind-Energy Facility.

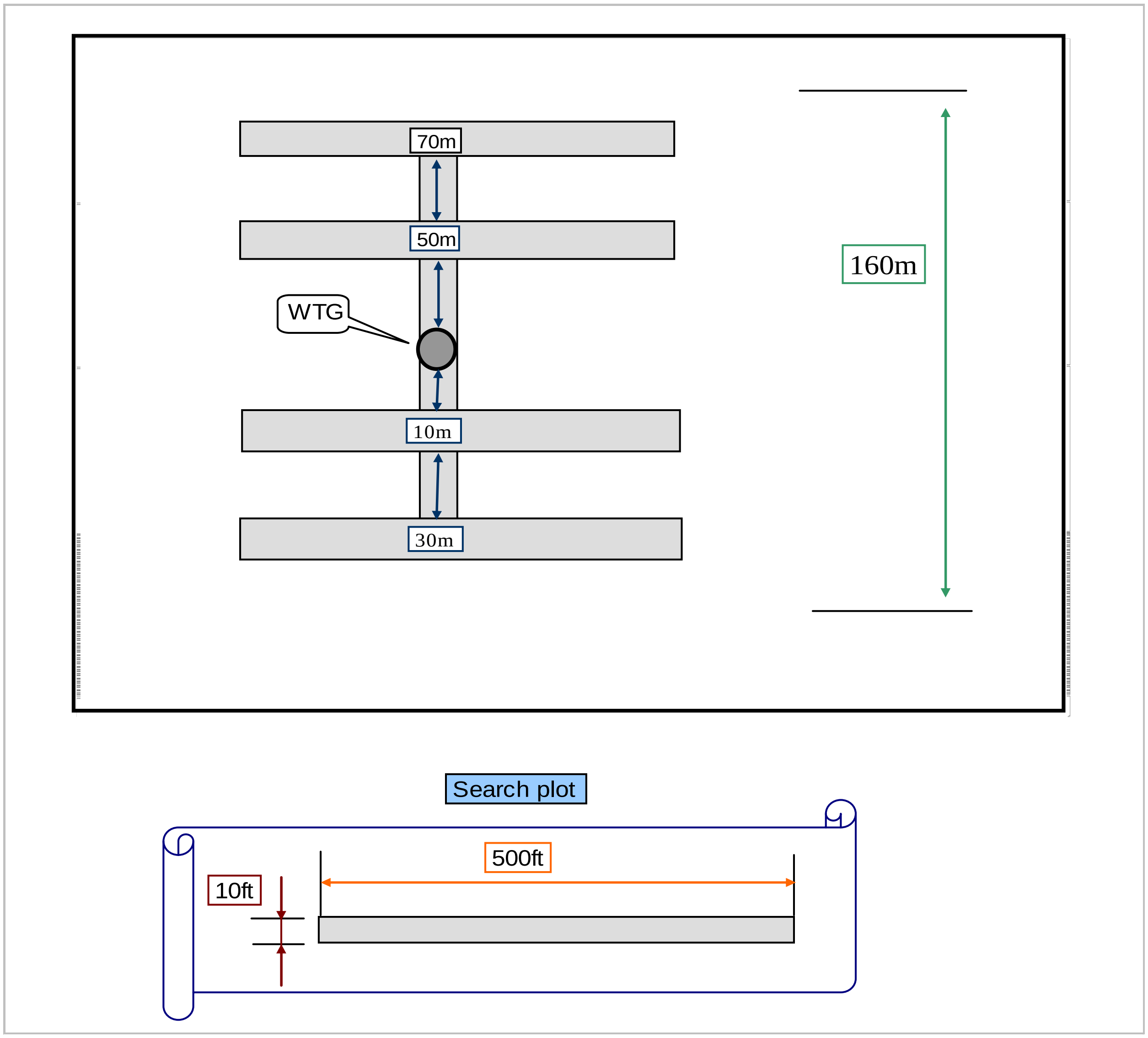

Figure 4. Example layout of carcass search transects.

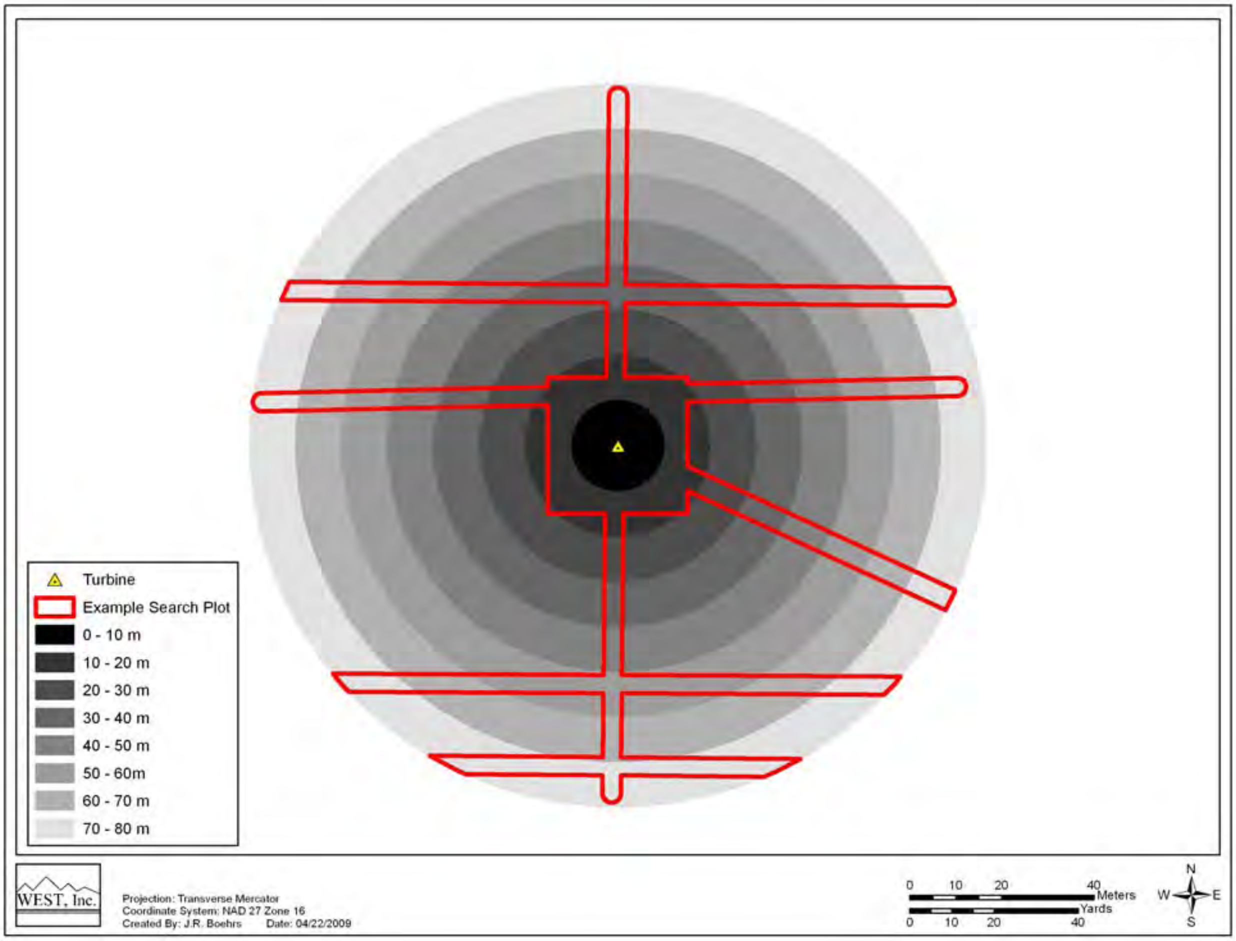

Figure 5. Illustration of proportion of each plot searched at varying distances from the turbine at the Fowler Ridge I Wind-Energy Facility.

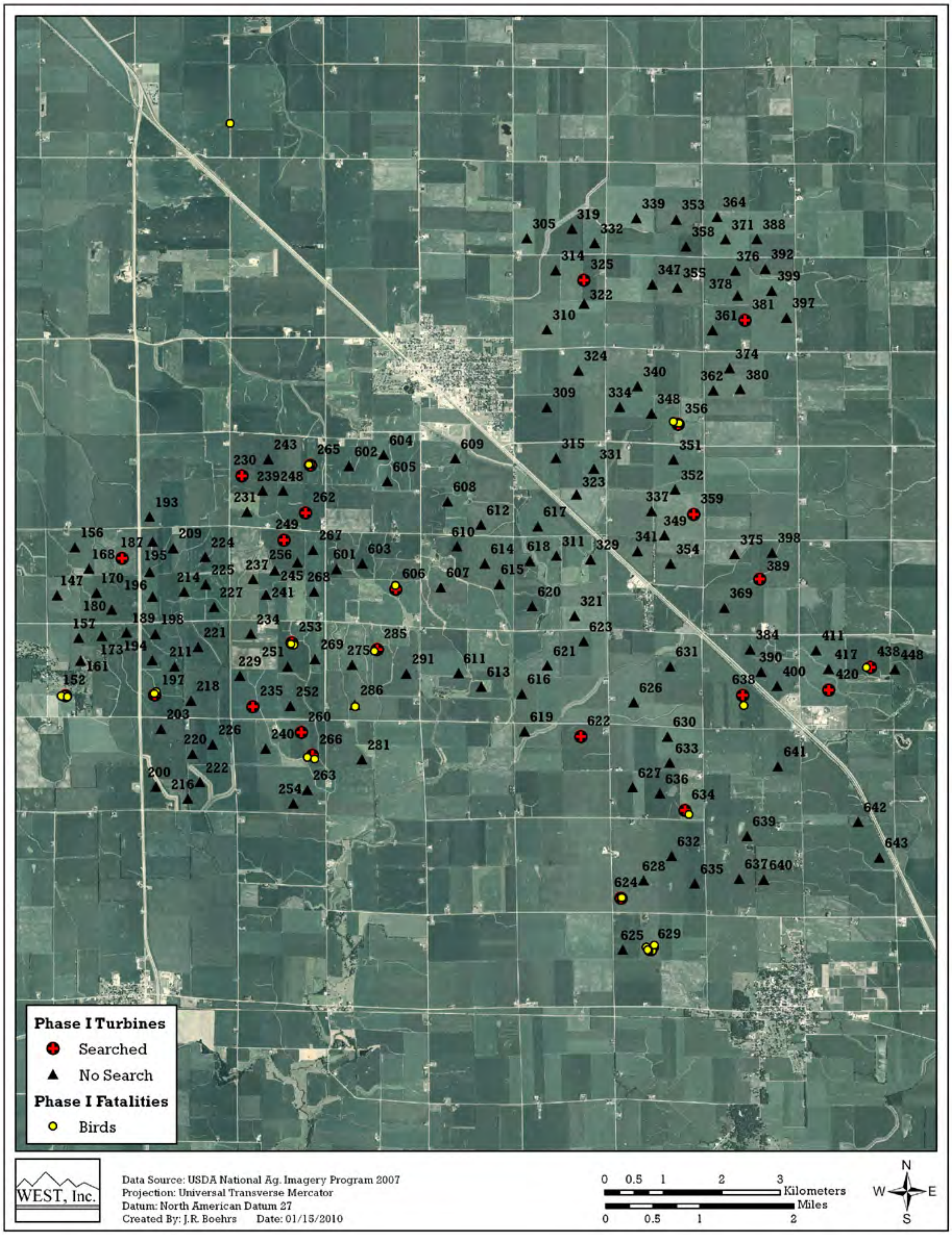

Figure 6. Location of bird casualties found at the Fowler Ridge I Wind-Energy Facility.

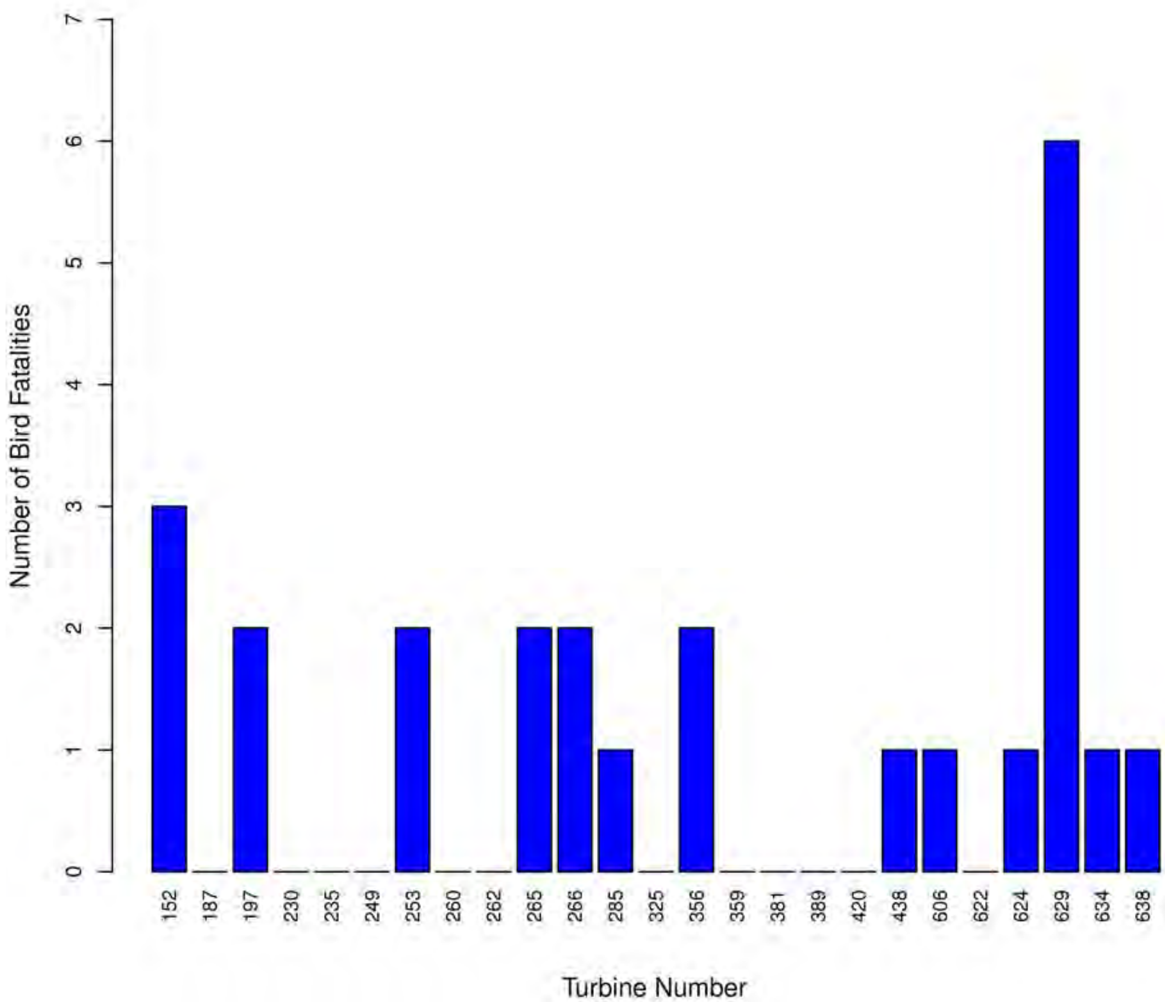

Figure 7. Number of bird fatalities by turbine at the Fowler Ridge I Wind-Energy Facility.

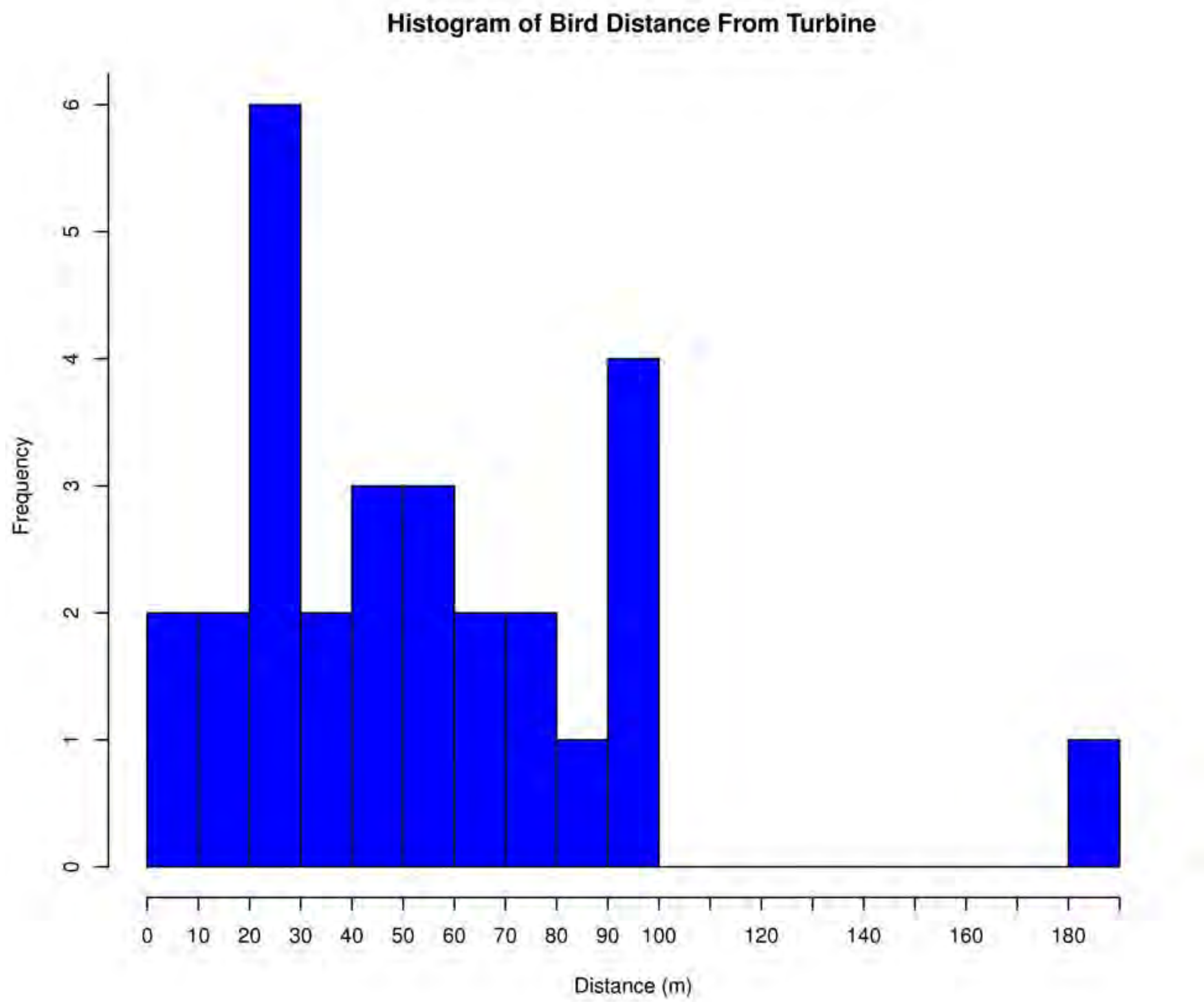

Figure 8. Distance of bird fatalities from the turbine at the Fowler Ridge I Wind-Energy Facility.

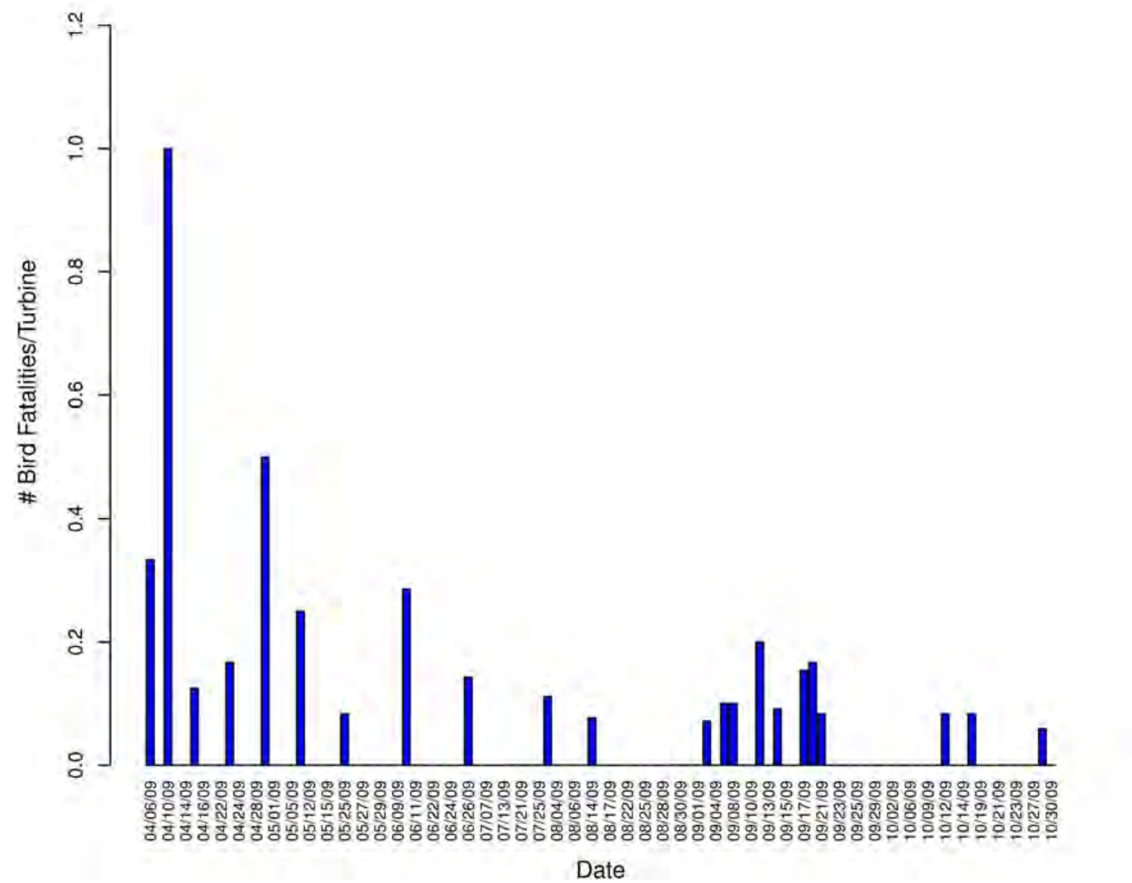

Figure 9. Timing of bird fatalities by turbine at the Fowler Ridge I Wind-Energy Facility.

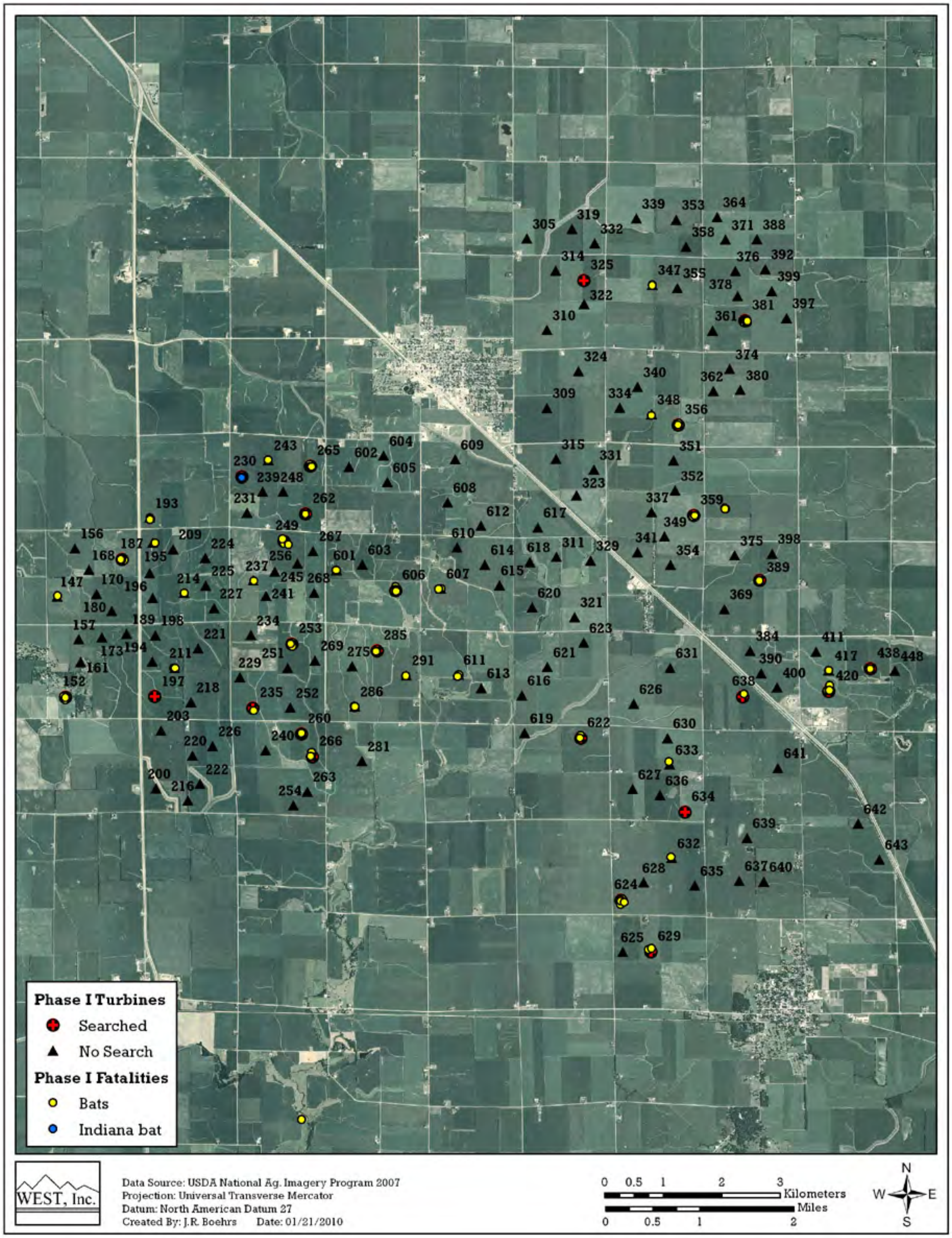

Figure 10. Location of bat casualties found at the Fowler Ridge I Wind-Energy Facility.

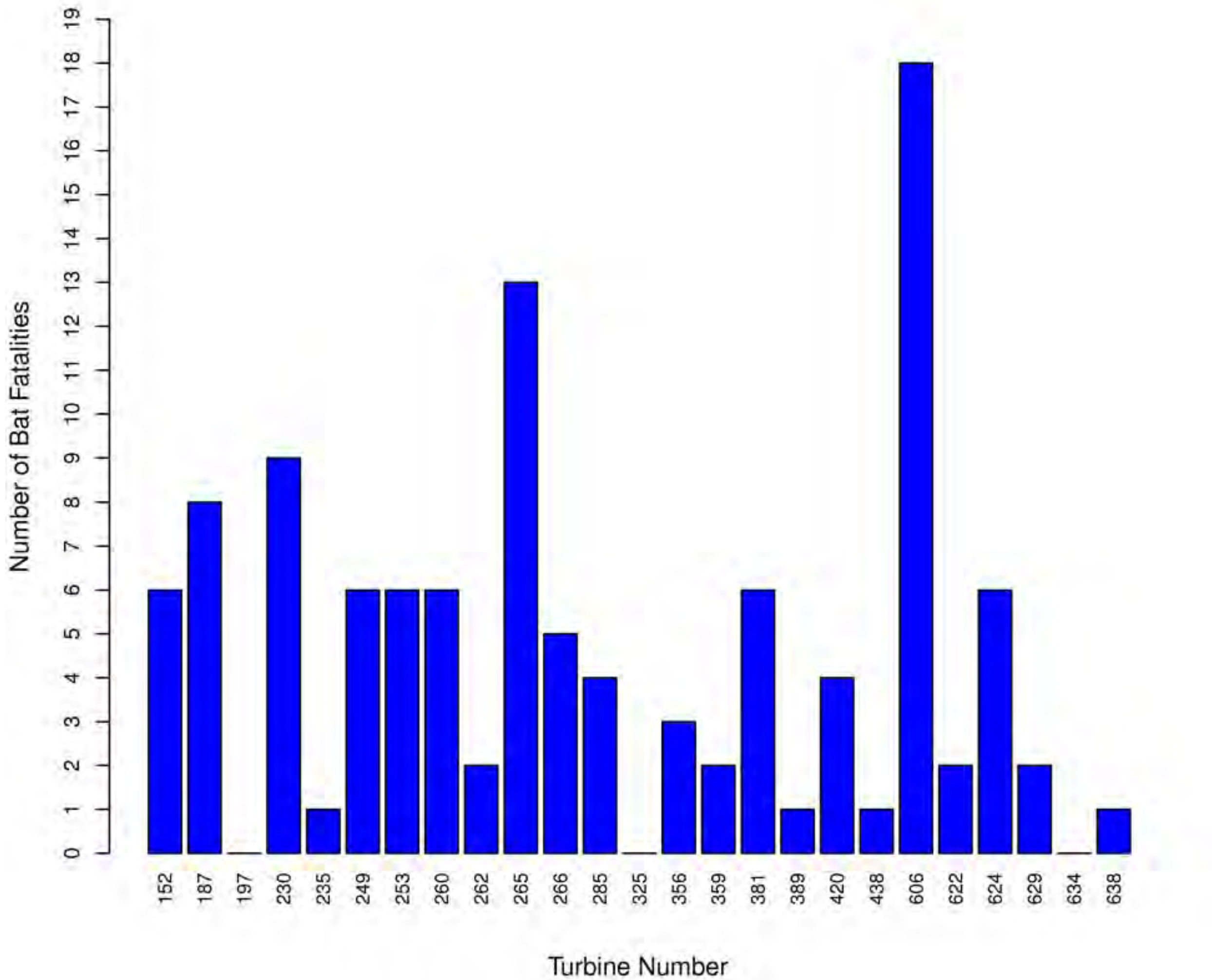

Figure 11. Number of bat fatalities by turbine at the Fowler Ridge I Wind-Energy Facility.

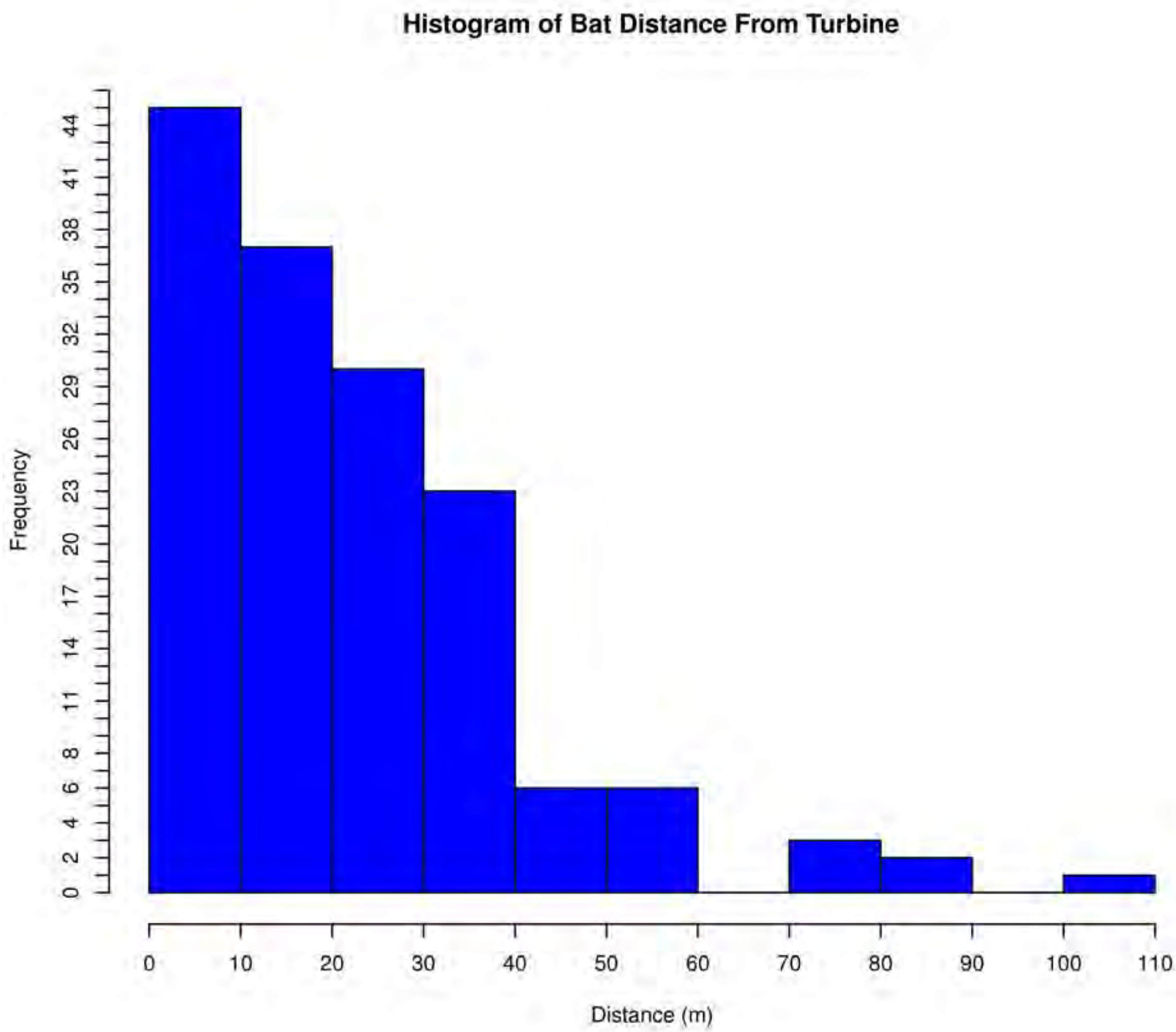

Figure 12. Distance of bat fatalities from the turbine at the Fowler Ridge I Wind-Energy Facility.

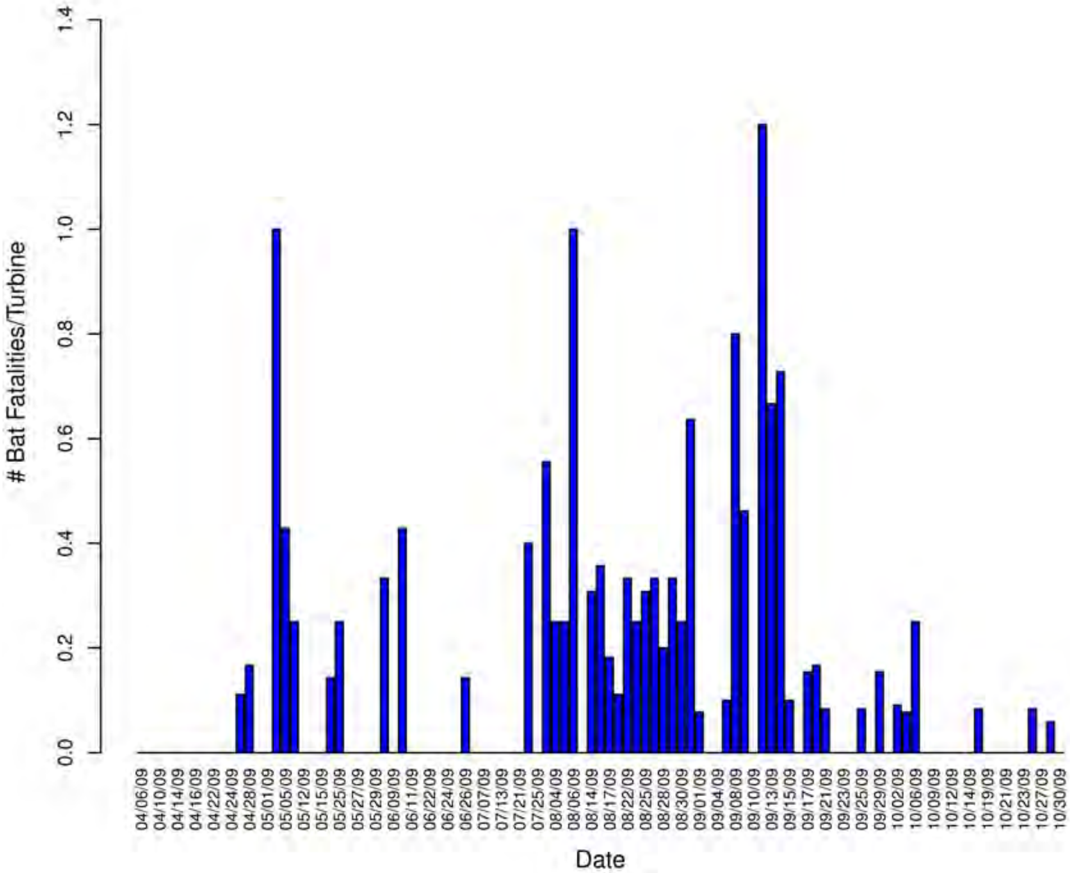

Figure 13. Timing of bat fatalities by turbine at the Fowler Ridge I Wind-Energy Facility.

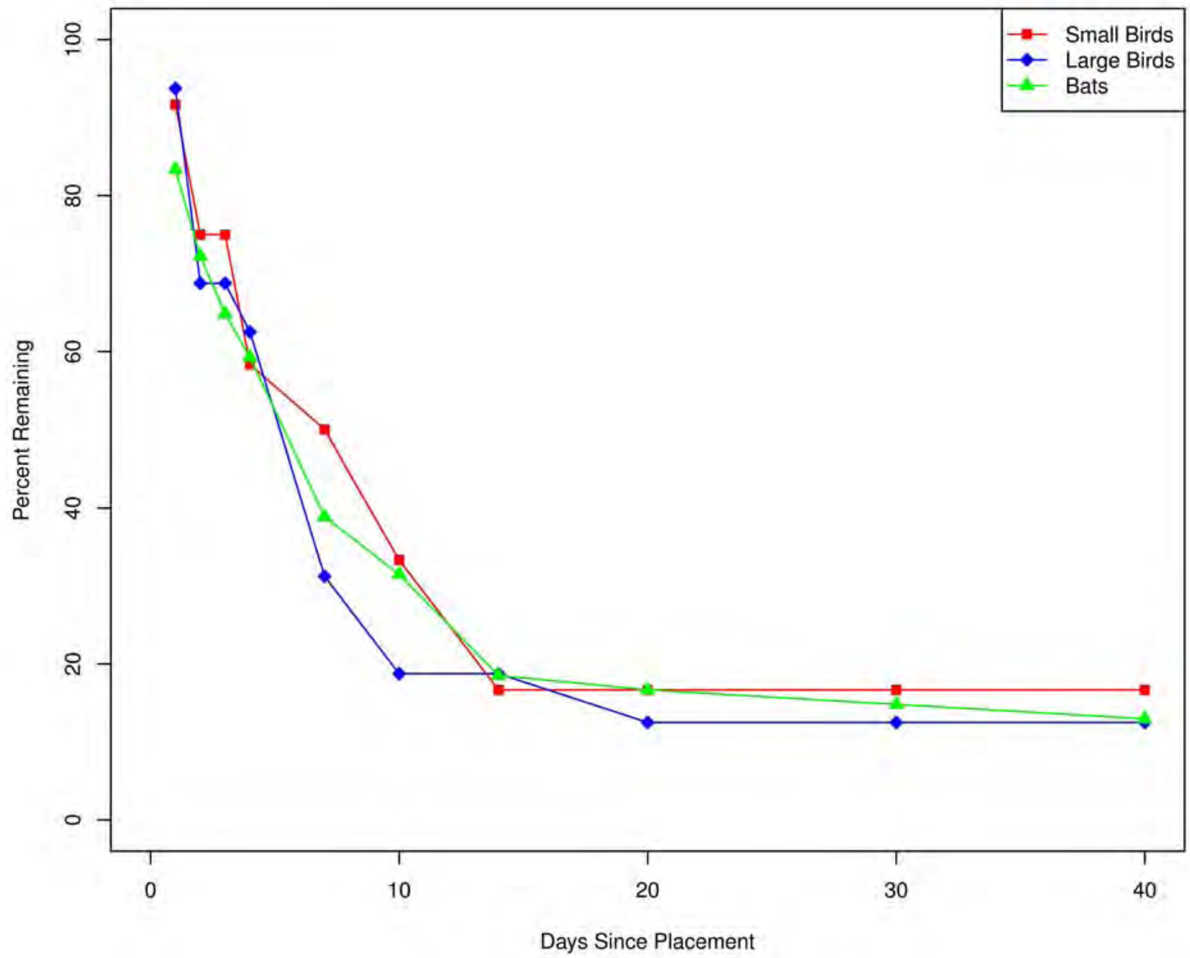

Figure 14. Carcass removal rates at the Fowler Ridge I Wind-Energy Facility.

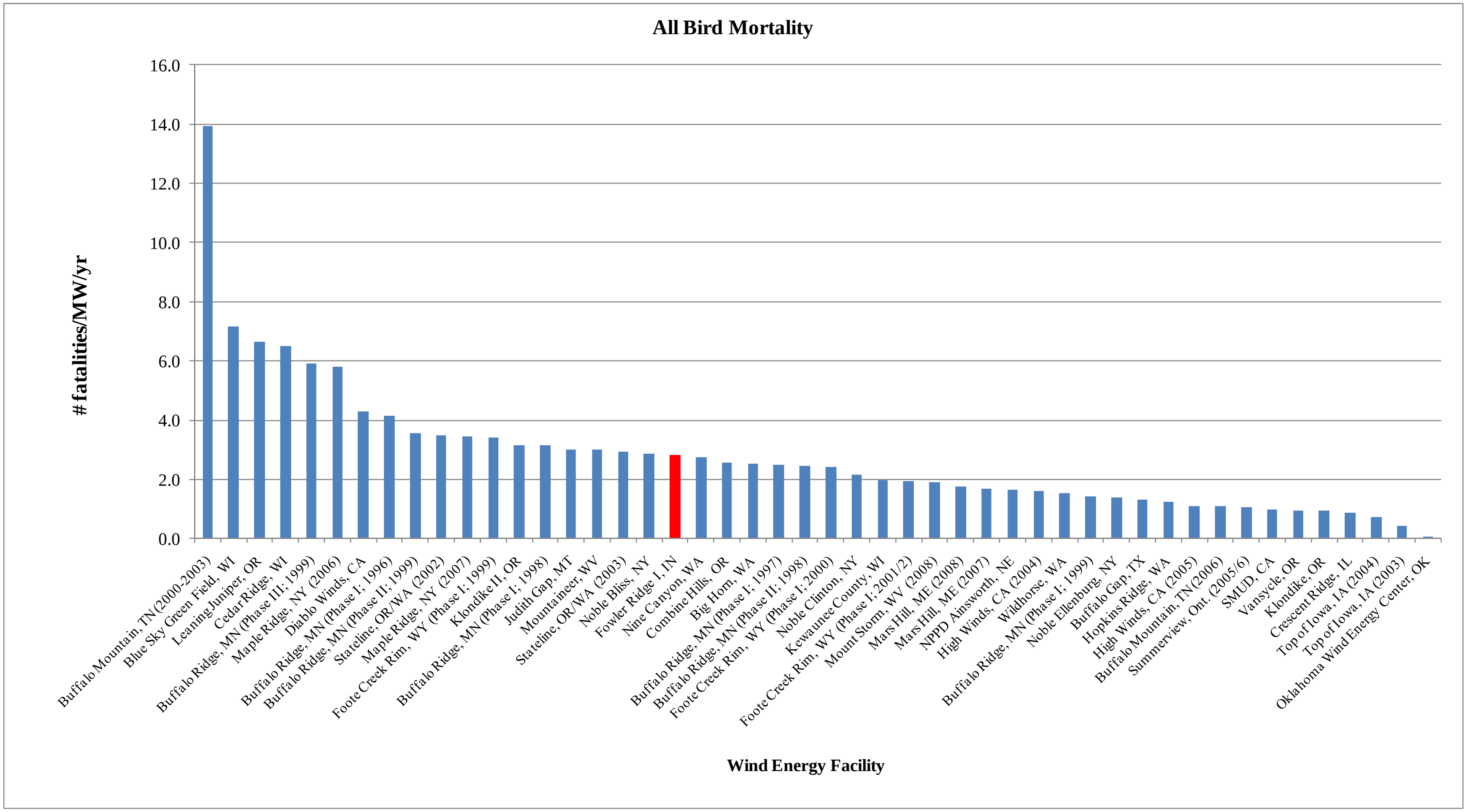

Figure 15. Bird mortality estimates across North America. The Fowler Ridge I Wind-Energy Facility is highlighted in red.

Figure 15 data sources:

Fowler Ridge I, IN	This study				
Buffalo Mountain, TN (00-03)	Nicholson et al. 2005	Nine Canyon, WA	Erickson et al. 2003	Noble Ellenburg, NY	Jain et al. 2009a
Blue Sky Green Field, WI	Gruver et al. 2010	Combine Hills, OR	Erickson et al. 2003	Buffalo Gap, TX	Tierney 2007
Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2000	Big Horn, WA	Kronner et al. 2008	Hopkins Ridge, WA	Young et al. 2007
Maple Ridge, NY (2006)	Jain et al. 2007	Buffalo Ridge, MN (Phase I; 97)	Johnson et al. 2000	High Winds, CA (05)	Kerlinger et al. 2006
Diablo Winds, CA	WEST 2008	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Buffalo Mountain, TN (06)	Fiedler et al. 2007
Buffalo Ridge, MN (Phase I; 96)	Johnson et al. 2000	Foote Creek Rim, WY (Phase I; 00)	Young et al. 2003a	Summerview, Ont. (05/06)	Brown and Hamilton 2006
Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	Noble Clinton, NY	Jain et al. 2009b	SMUD, CA	URS et al. 2005
Stateline, OR/WA (02)	Erickson et al. 2004	Kewaunee County, WI	Howe et al. 2002	Vansycle, OR	Erickson et al. 2000
Maple Ridge, NY (07)	Jain et al. 2008	Foote Creek Rim, WY (Phase I; 01/02)	Young et al. 2003a	Klondike, OR	Johnson et al. 2003b
Foote Creek Rim, WY (Phase I; 99)	Young et al. 2003a	Mount Storm, WV (08)	Young et al. 2009	Crescent Ridge, IL	Kerlinger et al. 2007
Klondike II, OR	NWC and WEST 2007	Mars Hill, ME (08)	Stantec 2009	Top of Iowa, IA (04)	Jain 2005
Buffalo Ridge, MN (Phase I; 98)	Johnson et al. 2000	Mars Hill, ME (07)	Stantec 2008	Erie Shores, Ont.	James 2008
Judith Gap, MT	TRC 2008	NPPD Ainsworth, NE	Derby et al. 2007	Top of Iowa, IA (03)	Jain 2005
Mountaineer, WV	Kerns and Kerlinger 2004	High Winds, CA (04)	Kerlinger et al. 2006	Oklahoma Wind Energy Center, OK	Piorkowski 2006
Stateline, OR/WA (03)	Erickson et al. 2004	Wildhorse, WA	Erickson et al. 2008	Searsburg, VT	Kerlinger 2002
Noble Bliss, NY	Jain et al. 2009c	Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000		

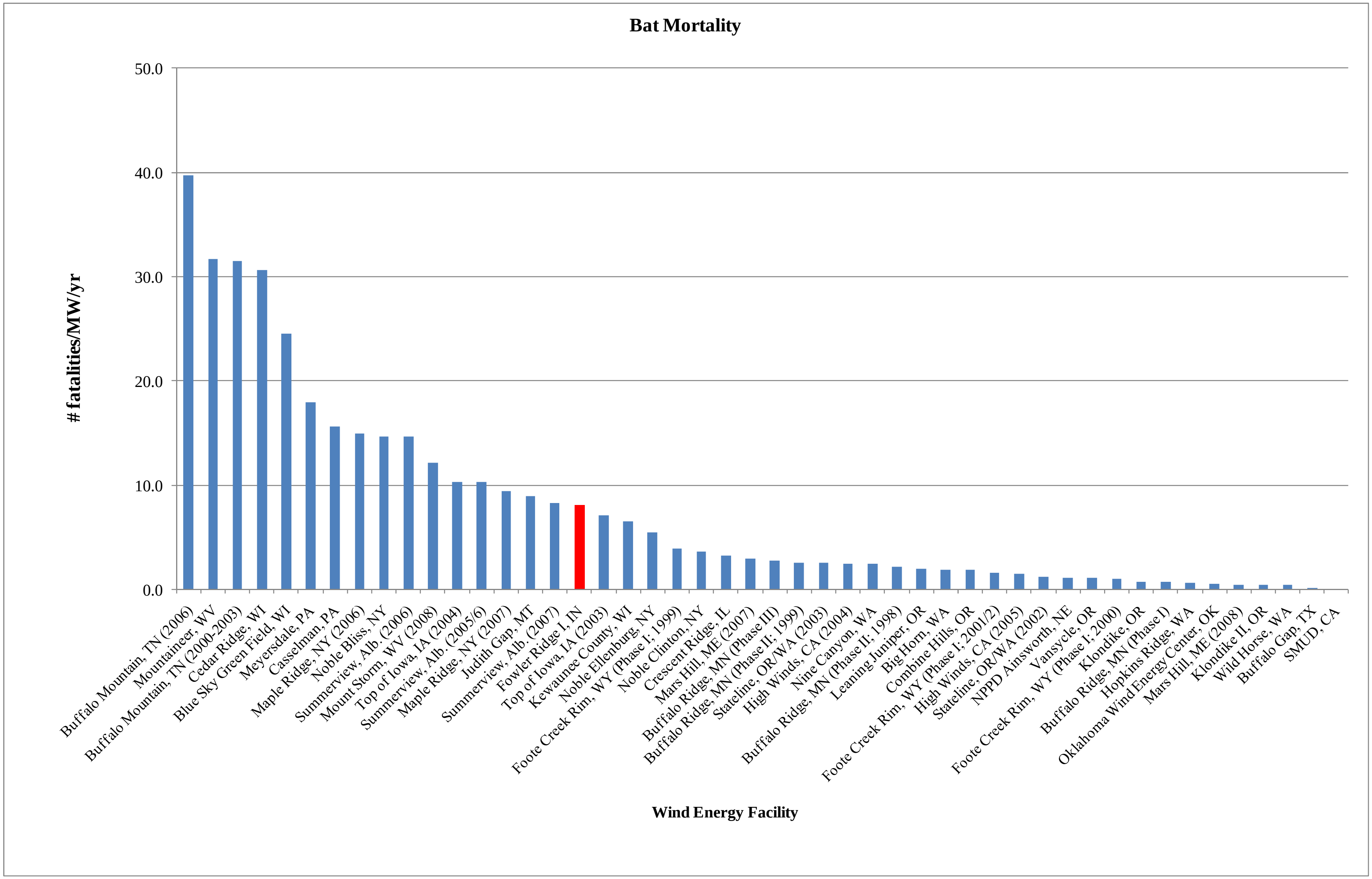

Figure 16. Bat mortality estimates across North America. The Fowler Ridge I Wind-Energy Facility is highlighted in red.

Figure 16 data sources:

Fowler Ridge I, IN	This study				
Buffalo Mountain, TN (06)	Fiedler et al. 2007	Kewaunee County, WI	Howe et al. 2002	Erie Shores, Ont.	James 2008
Mountaineer, WV	Kerns and Kerlinger 2004	Noble Ellenburg, NY	Jain et al. 2009a	Stateline, OR/WA (02)	Erickson et al. 2004
Buffalo Mountain, TN (00-03)	Nicholson et al. 2005	Foote Creek Rim, WY (Phase I; 99)	Young et al. 2003a	NPPD Ainsworth, NE	Derby et al. 2007
Blue Sky Green Field, WI	Gruver et al. 2010	Noble Clinton, NY	Jain et al. 2009b	Vansycle, OR	Erickson et al. 2000
Meyersdale, PA	Arnett et al. 2005	Crescent Ridge, IL	Kerlinger et al. 2007	Foote Creek Rim, WY (Phase I; 00)	Young et al. 2003a
Casselman, PA	Arnett et al. 2009	High Winds, CA (04)	Kerlinger et al. 2006	Klondike, OR	Johnson et al. 2003b
Maple Ridge, NY (06)	Jain et al. 2007	Mars Hill, ME (07)	Stantec 2008	Buffalo Ridge, MN (Phase I)	Johnson et al. 2000
Noble Bliss, NY	Jain et al. 2009c	Buffalo Ridge, MN (Phase III)	Johnson et al. 2000	Hopkins Ridge, WA	Young et al. 2007
Summerview, Alb. (06)	Baerwald 2008	Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	Oklahoma Wind Energy Center, OK	Piorkowski 2006
Mount Storm, WV (08)	Young et al. 2009	Stateline, OR/WA (03)	Erickson et al. 2004	Mars Hill, ME (08)	Stantec 2009
Top of Iowa, IA (04)	Jain 2005	Nine Canyon, WA	Erickson et al. 2003	Klondike II, OR	NWC and WEST 2007
Summerview, Alb. (05/06)	Brown and Hamilton 2006	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Wild Horse, WA	Erickson et al. 2008
Maple Ridge, NY (07)	Jain et al. 2008	Big Horn, WA	Kronner et al. 2008	Buffalo Gap, TX	Tierney 2007
Judith Gap, MT	TRC 2008	Combine Hills, OR	Young et al. 2006	SMUD, CA	URS et al. 2005
Summerview, Alb. (07)	Baerwald 2008	High Winds, CA (05)	Kerlinger et al. 2006	Searsburg, VT	Kerlinger 2002
Top of Iowa, IA (03)	Jain 2005	Foote Creek Rim, WY (Phase I; 01/02)	Young et al. 2003a		

Appendix A. Bird and Bat Casualties Found at the Fowler Ridge I Wind Energy Facility, Benton County, Indiana, April 6 – October 30, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/ Incidental
Birds					
4/6/2009	unidentified large bird	356	25	scavenged	carcass search
4/10/2009	unidentified large bird	629	60	scavenged	carcass search
4/15/2009	unidentified duck	629	35	scavenged	carcass search
4/23/2009	unidentified duck	629	85	scavenged	carcass search
4/29/2009	unidentified large bird	356	94	scavenged	carcass search
5/6/2009	blue-winged teal	629	43	scavenged	carcass search
5/25/2009	red-eyed vireo	197	59	intact	carcass search
6/10/2009	American robin	638	185	scavenged	incidental find
6/10/2009	unidentified bird	634	91	feather spot	carcass search
6/26/2009	brown-headed cowbird	197	21	intact	carcass search
8/3/2009	killdeer	253	49	scavenged	carcass search
8/14/2009	unidentified passerine	266	80	feather spot	carcass search
9/3/2009	killdeer	266	93	feather spot	carcass search
9/7/2009	mourning dove	629	97	feather spot	carcass search
9/8/2009	killdeer	606	68	feather spot	carcass search
9/8/2009	red-tailed hawk	286	36	intact	incidental find
9/11/2009	killdeer	265	16	intact	carcass search
9/14/2009	tree swallow	285	44	intact	carcass search
9/17/2009	tree swallow	253	24	intact	carcass search
9/17/2009	horned lark	624	14	intact	carcass search
9/18/2009	tree swallow	152	28	intact	carcass search
9/18/2009	Tennessee warbler	438	64	intact	carcass search
9/21/2009	Tennessee warbler	629	52	intact	carcass search
10/12/2009	green-winged teal	152	73	feather spot	carcass search
10/16/2009	house wren	152	30	scavenged	carcass search
10/20/2009	red-tailed hawk	354	8	scavenged	incidental find
10/26/2009	red-tailed hawk	470	8	scavenged	incidental find
10/29/2009	yellow-rumped warbler	265	30	intact	carcass search
Bats					
4/27/2009	silver-haired bat	266	74	scavenged	carcass search
4/28/2009	silver-haired bat	622	48	intact	carcass search
5/1/2009	silver-haired bat	632	12	intact	incidental find
5/4/2009	silver-haired bat	420	34	intact	carcass search
5/5/2009	little brown bat	265	32	intact	carcass search
5/5/2009	silver-haired bat	249	39	intact	carcass search
5/5/2009	silver-haired bat	265	29	intact	carcass search
5/6/2009	silver-haired bat	629	59	intact	carcass search
5/9/2009	silver-haired bat	633	56	scavenged	incidental find
5/21/2009	eastern red bat	629	60	intact	carcass search
5/25/2009	eastern red bat	187	40	intact	carcass search
5/25/2009	eastern red bat	253	35	intact	carcass search

Appendix A. Bird and Bat Casualties Found at the Fowler Ridge I Wind Energy Facility, Benton County, Indiana, April 6 – October 30, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/ Incidental
5/25/2009	silver-haired bat	249	31	intact	carcass search
6/8/2009	eastern red bat	420	17	intact	carcass search
6/10/2009	silver-haired bat	638	50	intact	carcass search
6/10/2009	silver-haired bat	624	31	intact	carcass search
6/10/2009	silver-haired bat	622	17	intact	carcass search
6/26/2009	hoary bat	265	12	intact	carcass search
7/23/2009	eastern red bat	187	1	intact	carcass search
7/23/2009	eastern red bat	187	3	intact	carcass search
7/28/2009	eastern red bat	286	2	intact	incidental find
8/3/2009	eastern red bat	265	19	intact	carcass search
8/3/2009	hoary bat	265	18	intact	carcass search
8/3/2009	hoary bat	606	21	intact	carcass search
8/3/2009	hoary bat	152	25	intact	carcass search
8/3/2009	eastern red bat	253	4	scavenged	carcass search
8/4/2009	hoary bat	260	3	intact	carcass search
8/5/2009	eastern red bat	381	11	intact	carcass search
8/5/2009	hoary bat	624	3	intact	carcass search
8/6/2009	hoary bat	482	37	intact	incidental find
8/6/2009	hoary bat	285	21	intact	incidental find
8/6/2009	hoary bat	482	3	intact	incidental find
8/14/2009	eastern red bat	187	8	intact	carcass search
8/14/2009	eastern red bat	249	38	intact	carcass search
8/14/2009	eastern red bat	265	11	intact	carcass search
8/14/2009	hoary bat	265	30	intact	carcass search
8/16/2009	eastern red bat	265	26	intact	carcass search
8/16/2009	eastern red bat	606	16	intact	carcass search
8/16/2009	hoary bat	262	30	intact	carcass search
8/16/2009	hoary bat	606	71	intact	carcass search
8/16/2009	hoary bat	260	15	intact	carcass search
8/17/2009	eastern red bat	356	37	scavenged	carcass search
8/17/2009	hoary bat	420	105	intact	carcass search
8/19/2009	eastern red bat	332	85	intact	incidental find
8/19/2009	eastern red bat	332	25	intact	incidental find
8/21/2009	eastern red bat	249	40	intact	carcass search
8/21/2009	hoary bat	356	10	scavenged	carcass search
8/22/2009	eastern red bat	260	5	intact	carcass search
8/22/2009	little brown bat	253	1	intact	carcass search
8/24/2009	eastern red bat	624	17	intact	carcass search
8/24/2009	eastern red bat	381	32	intact	carcass search
8/24/2009	silver-haired bat	381	1	intact	carcass search
8/25/2009	eastern red bat	265	32	scavenged	carcass search
8/25/2009	eastern red bat	606	19	intact	carcass search

Appendix A. Bird and Bat Casualties Found at the Fowler Ridge I Wind Energy Facility, Benton County, Indiana, April 6 – October 30, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/ Incidental
8/25/2009	hoary bat	265	14	intact	carcass search
8/25/2009	hoary bat	237	12	intact	incidental find
8/25/2009	northern long-eared bat	249	87	intact	carcass search
8/27/2009	eastern red bat	606	23	intact	carcass search
8/27/2009	eastern red bat	285	23	intact	carcass search
8/27/2009	hoary bat	249	53	scavenged	carcass search
8/27/2009	little brown bat	193	18	intact	incidental find
8/28/2009	big brown bat	193	4	intact	incidental find
8/28/2009	eastern red bat	266	21	intact	carcass search
8/28/2009	hoary bat	260	20	intact	carcass search
8/28/2009	silver-haired bat	348	13	intact	incidental find
8/29/2009	big brown bat	147	15	intact	incidental find
8/29/2009	silver-haired bat	381	27	intact	carcass search
8/30/2009	eastern red bat	417	2	intact	incidental find
8/30/2009	silver-haired bat	420	17	intact	carcass search
8/31/2009	eastern red bat	260	18	intact	carcass search
8/31/2009	eastern red bat	606	24	intact	carcass search
8/31/2009	eastern red bat	606	2	intact	carcass search
8/31/2009	hoary bat	260	26	intact	carcass search
8/31/2009	hoary bat	611	35	intact	incidental find
8/31/2009	hoary bat	611	0	intact	incidental find
8/31/2009	hoary bat	607	1	intact	incidental find
8/31/2009	hoary bat	607	35	intact	incidental find
8/31/2009	silver-haired bat	235	51	intact	carcass search
8/31/2009	silver-haired bat	606	13	intact	carcass search
8/31/2009	silver-haired bat	624	13	intact	carcass search
9/1/2009	hoary bat	152	26	scavenged	carcass search
9/7/2009	big brown bat	356	6	scavenged	carcass search
9/8/2009	eastern red bat	286	35	intact	incidental find
9/8/2009	eastern red bat	266	12	intact	carcass search
9/8/2009	eastern red bat	266	12	intact	carcass search
9/8/2009	eastern red bat	266	27	scavenged	carcass search
9/8/2009	eastern red bat	285	16	scavenged	carcass search
9/8/2009	hoary bat	230	48	intact	incidental find
9/8/2009	hoary bat	230	44	intact	incidental find
9/8/2009	hoary bat	606	8	intact	carcass search
9/8/2009	silver-haired bat	286	2	intact	incidental find
9/8/2009	silver-haired bat	286	33	intact	incidental find
9/8/2009	silver-haired bat	606	2	intact	carcass search
9/9/2009	eastern red bat	187	3	intact	carcass search
9/9/2009	hoary bat	230	30	intact	carcass search
9/9/2009	hoary bat	230	26	scavenged	carcass search

Appendix A. Bird and Bat Casualties Found at the Fowler Ridge I Wind Energy Facility, Benton County, Indiana, April 6 – October 30, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/ Incidental
9/9/2009	hoary bat	193	30	intact	incidental find
9/9/2009	hoary bat	187	23	scavenged	carcass search
9/9/2009	hoary bat	347	4	intact	incidental find
9/9/2009	silver-haired bat	438	2	intact	carcass search
9/9/2009	silver-haired bat	389	6	intact	carcass search
9/9/2009	silver-haired bat	347	16	scavenged	incidental find
9/10/2009	eastern red bat	372	24	intact	incidental find
9/10/2009	eastern red bat	372	21	intact	incidental find
9/10/2009	eastern red bat	470	12	intact	incidental find
9/10/2009	hoary bat	372	11	intact	incidental find
9/10/2009	hoary bat	372	17	intact	incidental find
9/11/2009	eastern red bat	243	3	intact	incidental find
9/11/2009	eastern red bat	606	4	intact	carcass search
9/11/2009	eastern red bat	291	1	intact	incidental find
9/11/2009	eastern red bat	291	9	nr[a]	incidental find
9/11/2009	hoary bat	230	25	intact	incidental find
9/11/2009	hoary bat	214	3	intact	incidental find
9/11/2009	hoary bat	211	17	intact	incidental find
9/11/2009	hoary bat	211	7	intact	incidental find
9/11/2009	hoary bat	262	1	intact	carcass search
9/11/2009	Indiana bat	230	16	intact	incidental find
9/11/2009	silver-haired bat	187	3	intact	carcass search
9/11/2009	silver-haired bat	214	3	intact	incidental find
9/11/2009	silver-haired bat	606	10	scavenged	carcass search
9/11/2009	silver-haired bat	195	47	intact	incidental find
9/13/2009	eastern red bat	601	8	intact	incidental find
9/13/2009	hoary bat	152	37	intact	carcass search
9/13/2009	hoary bat	152	43	intact	carcass search
9/13/2009	silver-haired bat	601	1	intact	incidental find
9/14/2009	eastern red bat	230	4	intact	carcass search
9/14/2009	eastern red bat	606	40	intact	carcass search
9/14/2009	eastern red bat	606	nr	intact	carcass search
9/14/2009	eastern red bat	285	22	intact	carcass search
9/14/2009	eastern red bat	152	33	intact	carcass search
9/14/2009	hoary bat	265	25	intact	carcass search
9/14/2009	hoary bat	253	19	intact	carcass search
9/14/2009	silver-haired bat	265	14	scavenged	carcass search
9/15/2009	hoary bat	417	3	scavenged	incidental find
9/15/2009	silver-haired bat	624	23	intact	carcass search
9/15/2009	silver-haired bat	417	6	scavenged	incidental find
9/17/2009	eastern red bat	606	33	intact	carcass search
9/17/2009	eastern red bat	253	34	intact	carcass search

Appendix A. Bird and Bat Casualties Found at the Fowler Ridge I Wind Energy Facility, Benton County, Indiana, April 6 – October 30, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/ Incidental
9/18/2009	hoary bat	187	15	intact	carcass search
9/18/2009	hoary bat	381	59	intact	carcass search
9/21/2009	hoary bat	359	27	intact	carcass search
9/25/2009	eastern red bat	253	16	intact	carcass search
9/25/2009	unident. *Lasiurus* bat	355	1	scavenged	incidental find
9/25/2009	eastern red bat	371	5	scavenged	incidental find
9/29/2009	silver-haired bat	624	74	intact	carcass search
9/29/2009	silver-haired bat	381	40	intact	carcass search
9/29/2009	silver-haired bat	425	nr	scavenged	incidental find
10/2/2009	eastern red bat	230	3	intact	carcass search
10/5/2009	silver-haired bat	359	18	intact	carcass search
10/6/2009	eastern red bat	152	30	intact	carcass search
10/6/2009	silver-haired bat	606	7	scavenged	carcass search
10/6/2009	silver-haired bat	230	27	intact	carcass search
10/12/2009	silver-haired bat	428	2	intact	incidental find
10/16/2009	silver-haired bat	265	24	intact	carcass search
10/26/2009	big brown bat	606	30	intact	carcass search
10/29/2009	silver-haired bat	606	14	intact	carcass search

[a] Found by turbine maintenance worker; not recorded.

Appendix B. Fatality estimates and components for birds at the Fowler Ridge I Wind-Energy Facility.

			90% C.I.				90% C.I.				90% C.I.	
Parameter	**mean**	**se**	**ll**	**ul**	**mean**	**se**	**ll**	**ul**	**mean**	**se**	**ll**	**ul**
		Spring				**Summer**				**Fall**		
Search Area Adjustment												
A (small)		1.00				1.00				3.67		
A (large)		1.00				1.00				9.63		
Observer Detection												
p (small)	0.38	0.14	0.17	0.58	0.38	0.14	0.17	0.58	0.38	0.14	0.17	0.58
p (large)	0.64	0.12	0.44	0.81	0.64	0.12	0.44	0.81	0.64	0.12	0.44	0.81
Observed Fatality Rates (Fatalities/turbine)												
Small birds												
$\bar{c}_i$ (Set 1[a])	0	0	0	0	0.33	0.19	0.08	0.69	0.25	0.13	0.07	0.46
$\bar{c}_i$ (Set 2[b])	0	0	0	0	0.08	0.08	0	0.21	0.38	0.18	0.11	0.69
Large birds												
$\bar{c}_i$ (Set 1)	0.08	0.08	0	0.21	0.08	0.08	0	0.22	0.25	0.12	0.08	0.47
$\bar{c}_i$ (Set 2)	0	0	0	0	0	0	0	0	0.15	0.13	0	0.43
All Birds												
$\bar{c}_i$ (Set 1)	0.08	0.08	0	0.21	0.42	0.20	0.12	0.82	0.5	0.17	0.25	0.81
$\bar{c}_i$ (Set 2)	0	0	0	0	0.08	0.08	0	0.21	0.54	0.22	0.25	0.97
Average Probability of Carcass Availability and Detection												
Small birds												
$\hat{\pi}_i$ (Set 1)	0.46	0.16	0.18	0.71	0.32	0.14	0.11	0.55	0.64	0.16	0.32	0.83
$\hat{\pi}_i$ (Set 2)	0.31	0.14	0.1	0.56	0.31	0.14	0.2	0.55	0.64	0.16	0.32	0.83
Large birds												
$\hat{\pi}_i$ (Set 1)	0.58	0.13	0.33	0.76	0.41	0.12	0.21	0.61	0.74	0.1	0.53	0.85
$\hat{\pi}_i$ (Set 2)	0.41	0.12	0.2	0.61	0.41	0.12	0.21	0.6	0.74	0.1	0.53	0.85
Adjusted Fatality Estimates (Fatalities/turbine)												
Small birds												
m_i (Set 1)	0	0	0	0	1.06	1.88	0.19	3.78	1.44	1.15	0.33	3.60

Appendix B. Fatality estimates and components for birds at the Fowler Ridge I Wind-Energy Facility.

			90% C.I.				90% C.I.				90% C.I.	
Parameter	**mean**	**se**	**ll**	**ul**	**mean**	**se**	**ll**	**ul**	**mean**	**se**	**ll**	**ul**
	Spring				**Summer**				**Fall**			
m_i (Set 2)	0	0	0	0	0.25	0.6	0	1.13	2.22	1.76	0.68	5.64
Large birds												
m_i (Set 1)	0.14	0.17	0	0.45	0.2	0.25	0	0.69	3.26	1.75	1.13	6.78
m_i (Set 2)	0	0	0	0	0	0	0	0	2.01	1.91	0	6.05
All birds												
m_i (Set 1)	0.14	0.17	0	0.45	1.25	1.9	0.33	3.92	4.7	2.09	2.41	9.14
m_i (Set 2)	0	0	0	0	0.25	0.6	0	1.13	4.23	2.61	1.81	9.57
Daily Fatality Estimates (Fatalities/turbine/day)												
Small birds												
m_i (Set 1)	0	0	0	0	0.012	0.022	0.002	0.044	0.019	0.015	0.004	0.047
m_i (Set 2)	0	0	0	0	0.003	0.007	0	0.013	0.029	0.023	0.009	0.073
Large birds												
m_i (Set 1)	0.004	0.004	0	0.011	0.002	0.003	0	0.008	0.042	0.023	0.015	0.088
m_i (Set 2)	0	0	0	0	0	0	0	0	0.026	0.022	0	0.07
All birds												
m_i (Set 1)	0.004	0.004	0	0.011	0.015	0.022	0.004	0.046	0.061	0.027	0.031	0.119
m_i (Set 2)	0	0	0	0	0.003	0.007	0	0.013	0.055	0.034	0.024	0.124

[a] Set 1 comprises of turbines with weekly, bi-weekly, and twice a week search intervals during spring, summer, and fall, respectively (Turbines 187, 197, 249, 253, 265, 266, 356, 381, 389, 420, 629, 634).

[b] Set 2 comprises of turbines with bi-weekly, bi-weekly, and twice a week search intervals during spring, summer, and fall, respectively (Turbines 152, 230, 235, 260, 262, 285, 325, 359, 438, 606, 622, 624, 638).

Appendix C. Fatality estimates and components for bats at the Fowler Ridge I Wind-Energy Facility.

Parameter	mean	se	90% C.I. ll	90% C.I. ul	mean	se	90% C.I. ll	90% C.I. ul	mean	se	90% C.I. ll	90% C.I. ul
		Spring				Summer				Fall		
Search Area Adjustment												
A		1.00				1.00				2.45		
Observer Detection												
p	0.56	0.07	0.44	0.69	0.56	0.07	0.44	0.69	0.56	0.07	0.44	0.69
Observed Fatality Rates (Fatalities/turbine)												
$\bar{c}_i$ (Set 1[a])	0.5	0.18	0.2	0.79	1.33	0.47	0.64	2.18	2.67	0.52	1.87	3.54
$\bar{c}_i$ (Set 2[b])	0.08	0.08	0	0.21	0.62	0.16	0.38	0.9	3.77	1.27	1.92	6
Average Probability of Carcass Availability and Detected												
$\hat{\pi}_i$ (Set 1)	0.51	0.06	0.40	0.61	0.35	0.06	0.25	0.45	0.35	0.06	0.25	0.45
$\hat{\pi}_i$ (Set 2)	0.34	0.06	0.25	0.44	0.35	0.06	0.25	0.45	0.68	0.06	0.58	0.77
Adjusted Fatality Estimates (Fatalities/turbine)												
m_i (Set 1)	0.99	0.38	0.38	1.65	3.81	1.62	1.74	6.86	9.61	2.07	6.46	13.35
m_i (Set 2)	0.22	0.23	0	0.66	1.78	0.59	1.03	2.96	13.60	4.84	6.67	22.51
Daily Fatality Estimates (Fatalities/turbine/day)												
d_i (Set 1)	0.02	0.01	0.01	0.04	0.04	0.02	0.02	0.08	0.12	0.03	0.08	0.17
d_i (Set 2)	0.01	0.01	0	0.02	0.02	0.01	0.01	0.03	0.18	0.06	0.09	0.29

[a]Set 1 comprises of turbines with weekly, bi-weekly, and twice a week search intervals during spring, summer, and fall, respectively (Turbines 187, 197, 249, 253, 265, 266, 356, 381, 389, 420, 629, 634).

[b]Set 2 comprises of turbines with bi-weekly, bi-weekly, and twice a week search intervals during spring, summer, and fall, respectively (Turbines 152, 230, 235, 260, 262, 285, 325, 359, 438, 606, 622, 624, 638).