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

April 2 – June 10, 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 third phase of the facility, Fowler Ridge III, is owned entirely by BPWENA and is located approximately two miles (3.2 km) east of Fowler, Indiana, and consists of 60 Vestas V82 1.65-MW turbines with a nameplate capacity of 99 MW.

BP Wind Energy North America contracted Western Ecosystems Technology, Inc. (WEST) to develop a post-construction fatality monitoring study at the Fowler I and Fowler III facilities to assess the level of impacts to birds and bats (i.e., high, moderate, low) relative to other wind-energy facilities from operation of the Fowler Ridge I and Fowler Ridge III facilities. Monitoring at the Fowler Ridge III Wind-Energy Facility occurred during the spring migration and early breeding season (April 2 through June 10, 2009), while monitoring of the Fowler I Wind-Energy Facility occurred from April 6 to October 30, 2009. This report presents results of monitoring conducted only at the Fowler III Wind-Energy Facility. Summer and fall migration surveys at the Fowler III Wind-Energy Facility were not conducted due to project-related budget constraints and the expectation that a more robust study would be conducted the second year.

The primary objective of the monitoring study was to determine the level of bird and bat mortality (i.e., relatively high, moderate, or low mortality) attributable to collisions with wind turbines compared to other regional wind-energy facilities. Because not all turbines were sampled, 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 consisted of four 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 remained in the field for possible detection; and 4) adjusted fatality estimates for birds and bats, calculated using the results from searcher efficiency trials and carcass removal trials, to estimate the approximate level of bird and bat mortality within the Fowler Ridge III Wind-Energy Facility.

Twenty percent of the available turbines (12 turbines) were scheduled to be searched either weekly or biweekly throughout the monitoring period. Search plots 160 meters (525 feet) on a side were established around each turbine to ensure all areas within 80 meters (262 feet) of a turbine were searched. Most of the turbines were located in corn and soybean fields; however, these crops were either not present or very immature during the time frame of the study (April 2 – June 10) and therefore no clearing of crops was conducted for this study. Surveyors walked parallel transects within the search plots while scanning the ground for fatalities or injured birds or bats.

The objective of the standardized carcass surveys was to systematically search selected turbines for bird and bat casualties attributable to collision with project facilities. During the study, three birds were found. All three of the fatalities were comprised only of a few bones without any feathers or fleshy parts remaining. Two of the fatalities were identifiable only as ducks based on

skull characteristics, while the remaining casualty was only identifiable as a large bird because no skull was present; that casualty was likely also a species of waterfowl. No bird fatalities were found incidentally. The FRWEF-III 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.

Two of the bird fatalities (the unidentified large bird and one unidentified duck) were found at Turbine 432 and the remaining unidentified duck casualty was found at Turbine 435. All bird fatalities were found greater than 60 meters (197 feet) from the turbines.

Five bat fatalities comprised of four species were found, including two hoary bats and one each of the following species: eastern red bat, silver-haired bat, and big brown bat. No bat casualties were found incidentally. Bat fatalities were all found at Turbines 387, 432, 435, 444, and 464. Two of the bat fatalities were found between 10 and 20 meters (33-66 feet) from the turbines, two were found between 40 and 50 meters (131-164 feet) from the turbines, and one was found more than 60 meters (197 feet) from the turbine. Bat fatalities were evenly distributed throughout the duration of the study season. Three bat fatalities were intact, one was scavenged, and one was found alive and was subsequently released.

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 none of the bat casualties found at the FRWEF-III in 2009 were high-frequency species (e.g., *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.

Searcher efficiency data from the adjacent Fowler Ridge Phase I Wind-Energy Facility were combined with data from this study to increase sample sizes, whereas all carcass removal data for the Fowler Ridge Phase I Wind-Energy Facility were used for this study. For searcher efficiency trials, 16 carcasses (eight large birds and eight small birds) were placed in the field during searcher efficiency trials conducted on two separate dates. Observer detection rates were 83.3% for large birds and 50.0% for small birds.

For carcass removal trials, 16 carcasses were placed in the Fowler Ridge Phase I Wind-Energy Facility, including eight large bird and eight small birds. By day ten, approximately 25% of the large birds remained, while approximately 35% of the small birds remained.

Because all three birds found during the study were estimated to have died well before the study was initiated, no estimates of avian mortality could be made. The estimated number of bat fatalities and associated 90% confidence limits for the study period from April 2 – June 10 was 3.03 bat fatalities/turbine (90% confidence interval of 0.71 to 6.58 bat fatalities/turbine). Based on the 1.65-megawatt capacity of turbines at the Fowler Ridge Phase III Wind-Energy Facility, the estimated number of bat fatalities was 1.84 bat fatalities per megawatt during the April 2 to June 10 study time period, or a total of 182 estimated bat fatalities for the entire 99-MW facility.

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 third phase of the facility, Fowler Ridge III, is owned entirely by BPWENA and is located approximately two miles (3.2 km) east of Fowler, Indiana, and consists of 60 Vestas V82 1.65-MW turbines with a nameplate capacity of 99 MW. The first and second phases of the wind-energy facility, Fowler I and Fowler II, are located directly west of the Fowler Ridge III Wind-Energy Facility (FRWEF-III). Fatality monitoring of the Fowler I Wind-Energy Facility (FRWEF-I) occurred from April 6 to October 30, 2009.

BPWENA contracted Western Ecosystems Technology, Inc. (WEST) to conduct a post-construction fatality monitoring study at the FRWEF-III to estimate the level of bird and bat mortality (i.e., relatively high, moderate, low mortality compared to other wind-energy facilities) during spring migration and the early summer breeding season. Fatality monitoring was conducted at the FRWEF-III from April 2 through June 10, 2009, during the spring migration and early summer breeding season. Summer and fall migration surveys at the Fowler III Wind-Energy Facility were not conducted due to project-related budget constraints and the expectation that a more robust study would be conducted the second year.

The monitoring study for the FRWEF-III 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 and carcass removal trials.

STUDY AREA

The Fowler Ridge Wind Resource Area (FRWRA) is located in western Indiana in Benton County (Figure 1), and lies within the Tipton Tall Plain physiographic region that includes much of central Indiana. This region was once heavily forested, but has lost almost all of its woodlands over the last 100 years (Mumford and Whitaker 1982). The topography of the FRWRA is mostly flat to slightly rolling and there are no hills, ridges, or other areas of starkly elevated topography. Elevations in the FRWRA range from approximately 700-800 ft (213-244 m). The area averages 40 inches (102 centimeters [cm]) of precipitation per year and temperatures range from 19 – 45 ^{0}F (-7.2-7.3 °C) in January to 65 – 86 ^{0}F (18-30 °C) in July. Soils in the 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 FRWRA is dominated by tilled agriculture, with corn (*Zea mays*) and soybeans (*Glycine max*) being the dominant crops. Of the roughly 80,400 acres (126.63 square miles [mi^2]) within the FRWRA, row crops compose about 90% of the area (Figure 2). After tilled agriculture, the next most common land use within the FRWRA area is pastures/hayfields, which compose 7.0%. There are 247 acres (0.39 mi^2) of grasslands, composing only 0.2% of the FRWRA. Grasslands in the project area are limited primarily to strips along drainages, railroad rights-of-way (ROW), and ROW along county and state roads. There are also a few grass-lined waterways within cultivated fields in the area. Trees in the FRWRA 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 FRWRA, and based on 1992 data, the 596 acres of forest present compose 0.7%.

METHODS

The primary objective of the monitoring study was to estimate the level (relatively high, moderate, or low) of bird and bat mortality attributable to collisions with wind turbines for the FRWEF–III during the spring migration and early summer breeding season. Because not all turbines were sampled, 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 and monitoring began on April 2 and continued through June 10, 2009. The methods for the fatality study are 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 and carcass removal trials to estimate the total number of bird and bat fatalities within the FRWEF-III.

There were three scenarios under which casualties were found in the FRWEF-III: 1) during the standardized surveys for the study; 2) while observers were at the FRWEF-III, but not conducting a standardized search (i.e., an incidental find); and 3) by facility personnel or others at the FRWEF-III 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), and searcher efficiency bias (percent found). 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 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

Square plots were established around 12 turbines (20% of the turbines) at the FRWEF-III 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) from the turbine were searched. The entire search plot was 6.3 acres (0.01 mi^2) in size. Studies at other facilities with large turbines, such as the Klondike wind-energy facility in Oregon (Johnson et al. 2003a), the Combine Hills facility, also in Oregon (Young et al. 2005), and the Crescent Ridge facility in Illinois (Kerlinger et al. 2007) indicate most fatalities are found within the area that is roughly equivalent to the height of the turbine tower. Most of the turbines were located in corn and soybean fields; however, these crops were either not present or very immature during the time frame of the study (April 2 – June 10) and therefore no clearing of crops was conducted as visibility on the search plots was considered adequate for detecting carcasses that may have been present.

During the spring migration period for most birds and bats (April 2 to May 15, 2009) standardized carcass surveys were conducted every seven days. The number of turbines searched each week during this period ranged from six to 12 turbines. For the last four weeks of surveys, all 12 turbines were searched every other week. To the extent possible, turbines were selected for sampling using a systematic design with a random start to ensure the search effort was spread throughout the entire wind-energy facility (Figure 3). However, some deviations in the turbine sampling design had to be made to accommodate landowners who did not wish to participate in the study.

Standardized Carcass Surveys

The objective of the standardized carcasses surveys was to systematically search wind turbines for bird and bat casualties that were attributable to collision with the turbines. 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 casualty 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, Global Positioning System (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 by carcass search technicians were treated following the above protocol as closely as possible. Casualties observed in non-search areas (e.g., near a turbine not included in the search area), or observed within search areas but outside of the standard search period, were coded as incidental discoveries and were documented in a similar fashion as those found during standard searches. Casualties found by 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 (birds only) and season. Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by searchers, allowing for a correction for detection bias.

Data from searcher efficiency trials conducted for the adjacent FRWEF-I study during the overlapping time period (April 2 to June 10) were combined with searcher efficiency data collected at the FRWEF-III to increase sample sizes. The same personnel conducted searches at both wind-energy facilities. Searcher efficiency trials were conducted on April 30 and May 27, 2009. Personnel conducting carcass surveys did not know when searcher efficiency trials were being conducted or the location of the trial carcasses. A total of 32 carcasses (16 large birds and 16 small birds) were placed for the two trials. 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*). Because only four dead bats were found during the study, sample sizes were not sufficient to use bats for searcher efficiency trials. Therefore, we used searcher efficiency data from small birds to adjust the estimated bat fatality rates.

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., tape or thread around the leg of the carcass) 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 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. Estimates of carcass removal were used to adjust the total number of carcasses found for those removed from the study area, correcting for removal bias.

Data from carcass removal trials conducted for the FRWEF-I study were used for the FRWEF-III study. A total of 16 carcasses were placed in the FRWEF-I twice during the monitoring period (May 1 and May 28), including eight large birds and eight small birds. Carcass composition was similar to that used for searcher efficiency trials. Because only four dead bats were found during this study, sample sizes were not sufficient to use bats for scavenger removal trials. We therefore assumed that removal rates for small birds would be similar to bats and used scavenger removal data for small birds to adjust the bat fatality estimate.

Removal trial birds were not placed in the standardized search plots in order to minimize the chance of confusing a trial bird 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.

Statistical Methods

Statistical Methods for Fatality Estimates

Estimates of facility-related fatalities are based on:

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

(2) Non-removal rates expressed as the estimated average probability a carcass is 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.

The numbers of 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 determined based on a cursory field necropsy. Total numbers of bird and bat carcasses were estimated by adjusting for removal and searcher efficiency bias. 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.

Definition of Variables

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 per monitoring period is determined by:

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

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 ($\bar{t}$) is the average length of time a carcass remains in the study area before it is removed:

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

Estimation of Searcher Efficiency Rates

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

Estimation of Facility-Related Fatality Rates

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

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

where $\hat{\pi}$ includes 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 $\hat{\pi}$.

$\hat{\pi}$ is 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 were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. For each bootstrap sample, $\bar{c}$, $\bar{t}$, p, $\hat{\pi}$, and m are calculated. A total of 5,000 bootstrap samples were used and the reported estimates are 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 90% confidence intervals.

RESULTS

Standardized Carcass Surveys

The 12 turbines representing 20% of all turbines within the FRWEF-III were searched over the course of the fatality monitoring study for a total of 83 turbine searches. A total of three birds and five bats were found during standardized carcass surveys, and no additional fatalities were found incidentally (Appendix A). One of the bats (hoary bat [*Lasiurus cinereus*]) was found alive, and was subsequently released after discovery. The number, species, location, other characteristics of the bird and bat fatalities, and the fatality estimates adjusted for searcher efficiency and carcass removal biases are discussed below.

Bird Fatalities

During the study, three birds were found. All three of the fatalities were comprised only of a few bones without any feathers or fleshy parts remaining. Two of the fatalities were identifiable only as ducks based on skull characteristics, while the one remaining casualty was only identifiable as a large bird because the skull was not present; however, this casualty was likely also a duck. No bird fatalities were found incidentally. The bird fatalities were found on April 13, 22, and 30, 2009.

Two of the birds (the unidentified large bird and one unidentified duck) were found at Turbine 432, and the remaining unidentified duck casualty was found at Turbine 435 (Figure 4). All bird fatalities were found more than 60 m (197 ft) from the turbines. All bird fatalities were estimated to have been present at least two weeks to one month before the study was initiated.

Bat Fatalities

Five bat fatalities comprised of four species were found, including two hoary bats and one each of the following species: eastern red bat (*Lasiurus borealis*), silver-haired bat (*Lasionycteris noctivagans*), and big brown bat (*Eptesicus fuscus*; Appendix A). No bat casualties were found incidentally.

The five bat fatalities were found at Turbines 387, 432, 435, 444, and 464 (Figure 5). Given the small number of bats found, no statistical tests were conducted to compare fatalities among different locations. Of the bat fatalities, two (40.0%) were found between 10-20 m (33-66 ft) from the turbines, two (40.0%) were found between 40-50 m (131-164 ft) from the turbines, and one (20.0%) was found more than 60 m from the turbine.

Bat fatalities were found on April 30 (three fatalities), May 26 (one), and June 10, 2009 (one). Three bat fatalities were intact, one was scavenged, and one hoary bat was found alive and was subsequently released. Two of the fatalities were estimated to have occurred the previous night and two were estimated to have died from four to seven days before they were found.

Searcher Efficiency Trials

A total of 16 carcasses (eight large birds and eight small birds) were placed in the field during searcher efficiency trials conducted on two separate dates (April 30 and May 27). Observer detection rates were 83.3% for large birds and 50.0% for small birds (Table 1).

Carcass Removal Trials

A total of 16 carcasses were placed in the field during the study period (May 1 and May 28), including eight large birds and eight small birds. By day ten, approximately 25% of the large birds remained, while approximately 35% of the small birds remained (Figure 6).

Adjusted Fatality Estimates

Because all three birds found during the study were estimated to have died well before the study was initiated, no estimates of avian mortality could be made. Fatality estimates, standard errors, and confidence intervals were calculated for bats (Table 2). Based on searcher efficiency and the carcass removal rate at the site, the estimated average probability that a bird casualty would remain in the plot until a scheduled search and would be found during the study season, when turbines were searched weekly, was about 50% for large birds and about 39% for small birds. For turbines searched biweekly, these probabilities were approximately 30% for small birds and about 39% for large birds. The estimated average probability a bat casualty would remain until a scheduled search and be found was about 43% for turbines searched weekly and approximately 34% for turbines search biweekly.

The estimated number of bat fatalities and associated 90% confidence limits for the April 2 – June 10 study period was 3.03 bat fatalities/turbine (90% confidence interval of 0.71 to 6.58 bat fatalities/turbine; Table 2). Based on the 1.65-MW capacity of turbines at the FRWEF-III, the estimated number of bat fatalities was 1.84 bat fatalities per MW during the April 2 to June 10 study time period, or a total of 182 bat fatalities for the entire 99-MW facility.

DISCUSSION

Fatality Estimation

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, searcher efficiency rates, and carcass removal rates. It is hypothesized that scavenging could change through time at a given area and must be accounted for when attempting to estimate fatality rates. We accounted for this by conducting scavenging trials throughout the study 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 bat fatality rates based on the search interval. Overlapping confidence intervals for overall fatality estimates based on weekly and biweekly search intervals (Table 2) indicate that the estimates were consistent regardless of search interval. However, estimates derived from the weekly searches are likely most reliable.

There are numerous factors that could contribute to both positive and negative biases in estimating fatality rates (Erickson 2006). The overall design of this study incorporates several assumptions or factors that affect the results of the fatality estimates. First, all bird casualties found within the standardized search plots during the study were included in the analysis. No carcasses found during this study were found incidentally within a search plot during other activities at the FRWEF-III. Second, it was assumed that all carcasses found during the study were due to collision with wind turbines. 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). 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. Plot boundaries 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 (Erickson et al. 2004; Johnson et al. 2002, 2003b, 2004; Kerlinger et al. 2007; Higgins et al. 1996; Young et al. 2003, 2005) in which a distance equal to the approximate height of the turbine appeared to contain a vast majority of fatalities. Based on the distribution of fatalities as a function of distance from turbines, 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 and whether or not they are representative of actual carcasses. This may occur if the types of birds used are larger or smaller than the carcasses of actual fatalities, or if the trial carcasses are more or less cryptic in color than the actual fatalities. Mallards, ring-necked pheasants, northern bobwhites, and house sparrows were used to represent the range of bird fatalities expected. It is believed that this range captures the range of sizes and other characteristics of actual fatalities and should be a reasonable representation of scavenging rates of the birds as a group. Additionally, due to a lack of bat fatalities to use for trials, data from small birds were used to estimate searcher efficiency and scavenging rates for bats. Although small birds were likely a good surrogate for bats in searcher efficiency trials, scavenging rates may differ between small birds and bats.

Bird Fatalities

Of the three birds that were found during scheduled searches (none found incidentally), there were no identifiable raptors or sensitive or protected species. Because all three birds were estimated to have died well before the study was initiated, it was not possible to estimate total avian fatality. Given that no birds were found that were estimated to have died during the study period, it appears that avian fatality at the FRWEF-III was very low during the April 2 – June 10 time period that this study was conducted. 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. The FRWEF-III 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.

Based on the apparently very low avian mortality during the time frame of this study at the FRWEF-III, and assuming that mortality during other portions of the year is not substantially higher, then it is unlikely that operation of this facility will result in any significant impacts to bird populations, as has been the case at other wind-energy facilities across North America (Johnson and Stephens 2010).

Bat Fatalities

The estimated bat fatality rate at the FRWEF-III of 1.84 bats/MW during the study period is likely an underestimate of actual bat mortality as this study did not cover the fall migration period, when most bat mortality occurs at other wind-energy facilities across North America (Arnett et al. 2008, Johnson 2005). Therefore, bat mortality estimates from the FRWEF-I, which was studied during the spring, summer, and fall (Johnson et al. 2010), likely provide a better indicator of actual bat mortality at the FRWEF-III. 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. 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).

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 none of the bat casualties found at the FRWEF-III 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 facilities, 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-III. 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 fatalities at the FRWEF-III was similar to that at most other wind-energy facilities, in that 80% of the fatalities were comprised of migratory tree bats, namely the hoary and eastern red bat. Based on the timing of fatalities for these species and the lack of forest cover that might provide habitat for resident bats, most of the fatalities were apparently migrants through the FRWEF-III, 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-III is located along a concentrated bat migration route, as there are no topographical features or large expanses of forested areas that would tend to concentrate migrating bats. 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 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 deoxyribonucleic acid (DNA) sequences 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 (Amy L. Russell, Assistant Professor, Grand Valley State University, Allendale, Michigan, pers. comm.). To date, initial analyses have been conducted only for the 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.

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

Size	Date	# Placed	# Available	# Found	% Found
Small Birds	4/30/2009	4	2	2	100
	5/27/2009	4	4	1	25
	Overall	**8**	**6**	**3**	**50**
Large Birds	4/30/2009	4	2	1	50
	5/27/2009	4	4	4	100
	Overall	**8**	**6**	**5**	**83.3**

Table 2. Fatality estimates and components for bats for the Fowler Ridge III Wind-Energy Facility.

Parameter	mean	se	90% C.I. ll	90% C.I. ul	mean	se	90% C.I. ll	90% C.I. ul
Search Area Adjustment								
A	1.00							
Observer Detection								
p	0.51	0.18	0.25	0.75				
	Weekly Searches				**Biweekly Searches**			
Observed Fatality Rates (Fatalities/turbine)								
$\bar{c}_i$	0.34	0.20	0	0.67	0.51	0.20	0.20	0.83
Average Probability of Carcass Availability and Detected								
$\hat{\pi}_i$	0.43	0.17	0.17	0.70	0.34	0.15	0.11	0.60
Adjusted Fatality Estimates (Fatalities/turbine)								
m_i	0.96	0.91	0	2.46	2.04	1.86	0.50	4.69
Daily Fatality Rates (Fatalities/turbine/day)								
d_i	0.014	0.013	0	0.035	0.029	0.027	0.007	0.067
Overall (All Turbines Combined) Adjusted Fatality Estimates (Fatalities/turbine)								
	3.03	**2.84**	**0.71**	**6.58**				

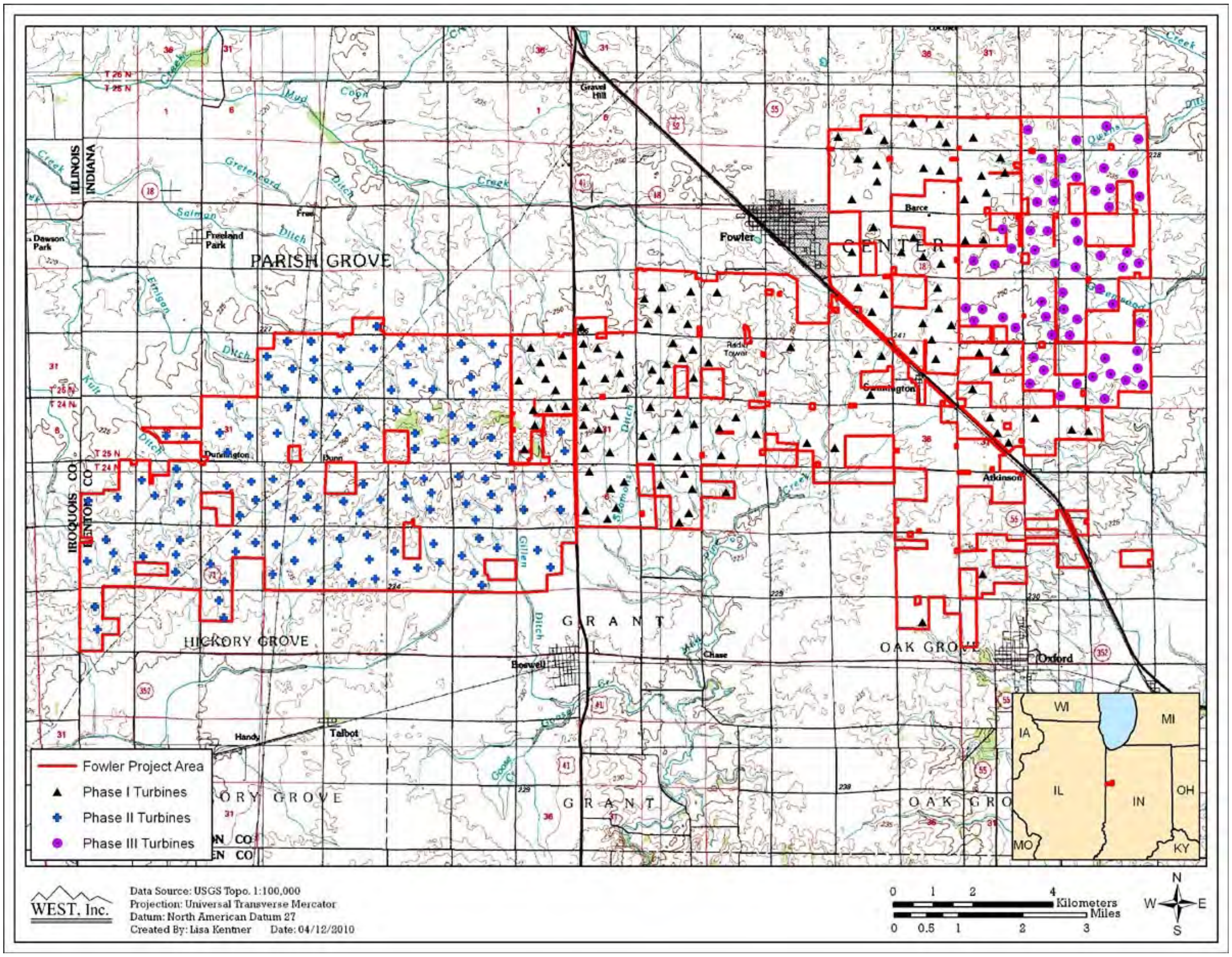

Figure 1. Location of the Fowler Ridge Wind-Energy Facility in Benton County, Indiana.

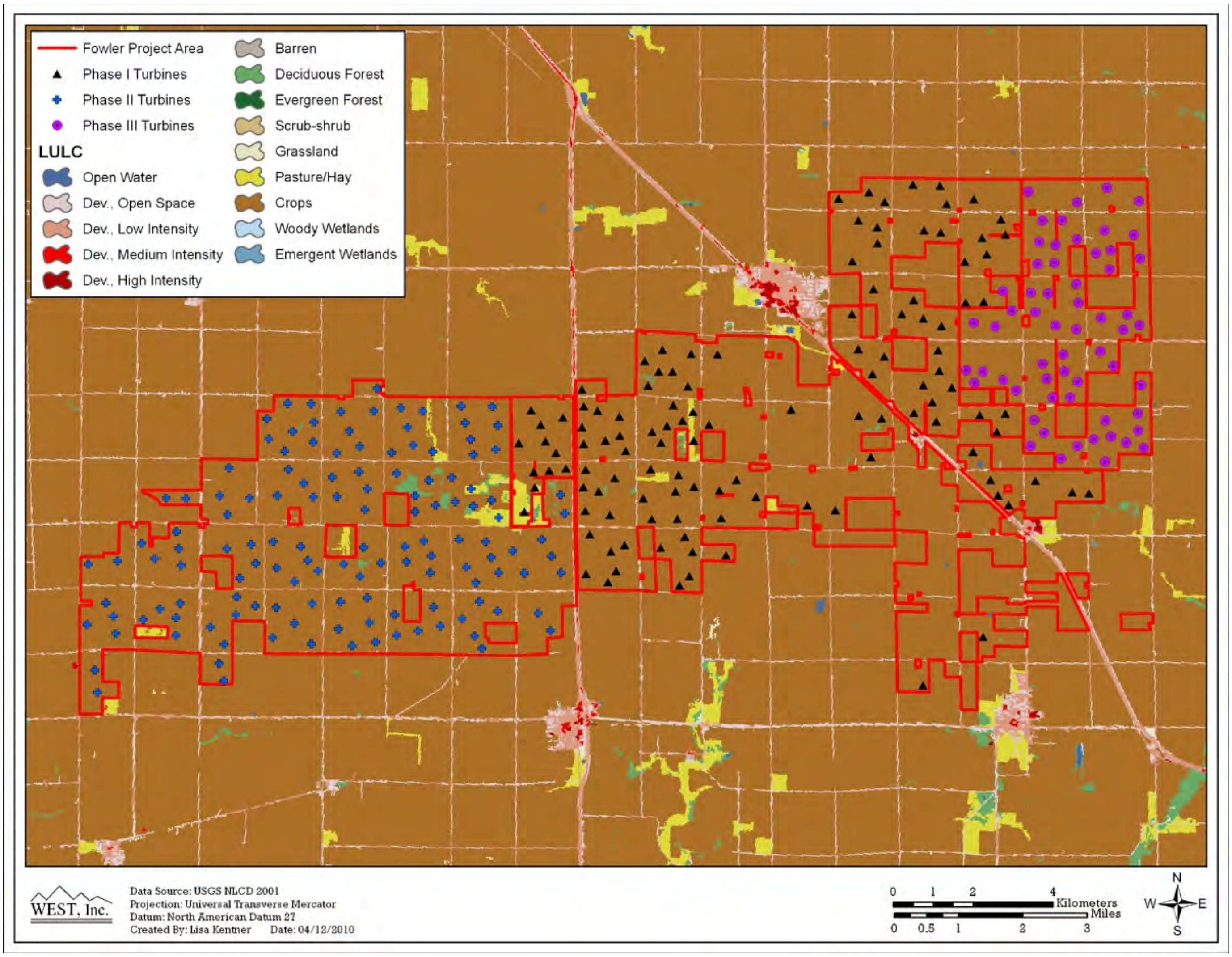

Figure 2. Landcover types at the Fowler Ridge III Wind-Energy Facility.

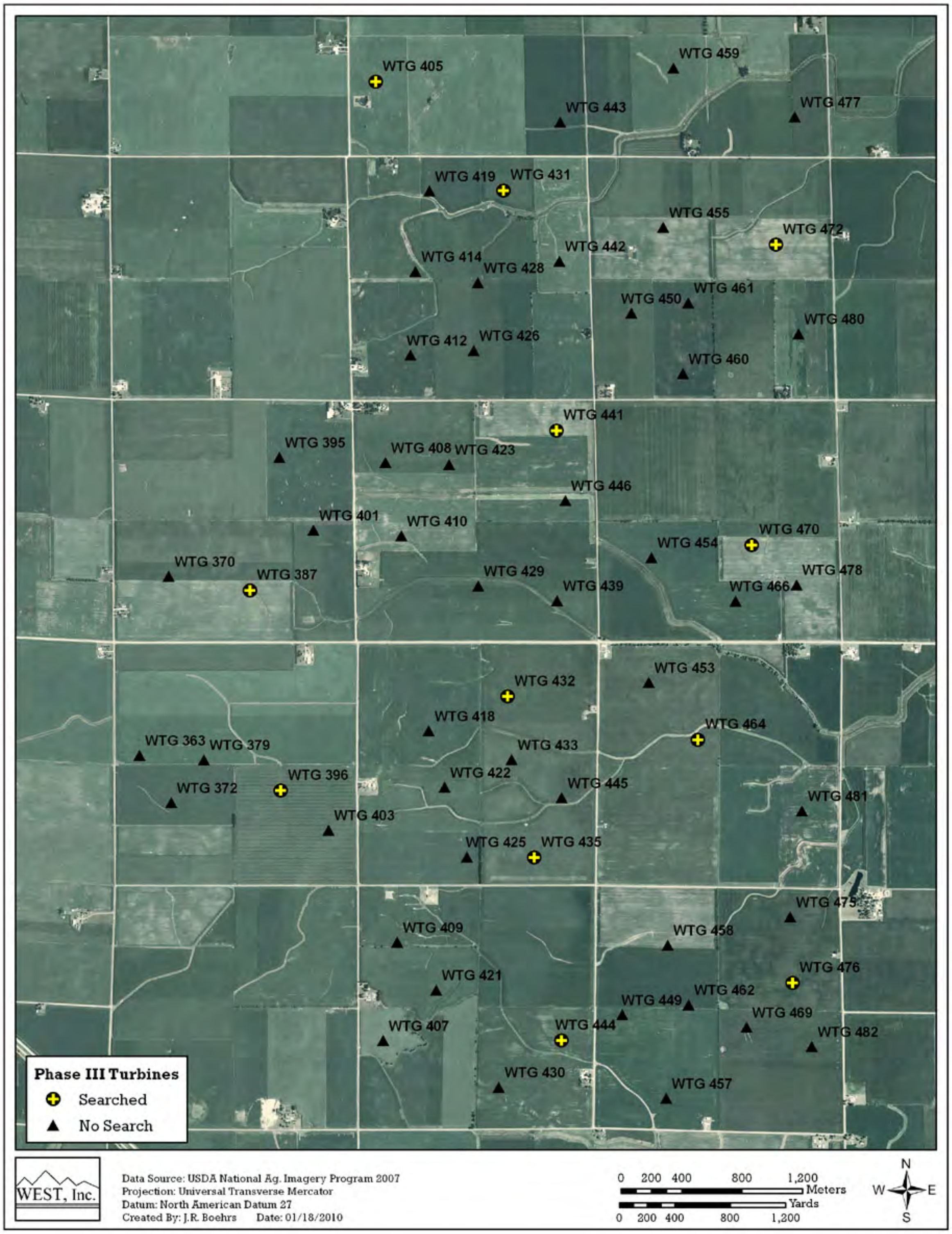

Figure 3. Location of carcass search plots at the Fowler Ridge III Wind-Energy Facility.

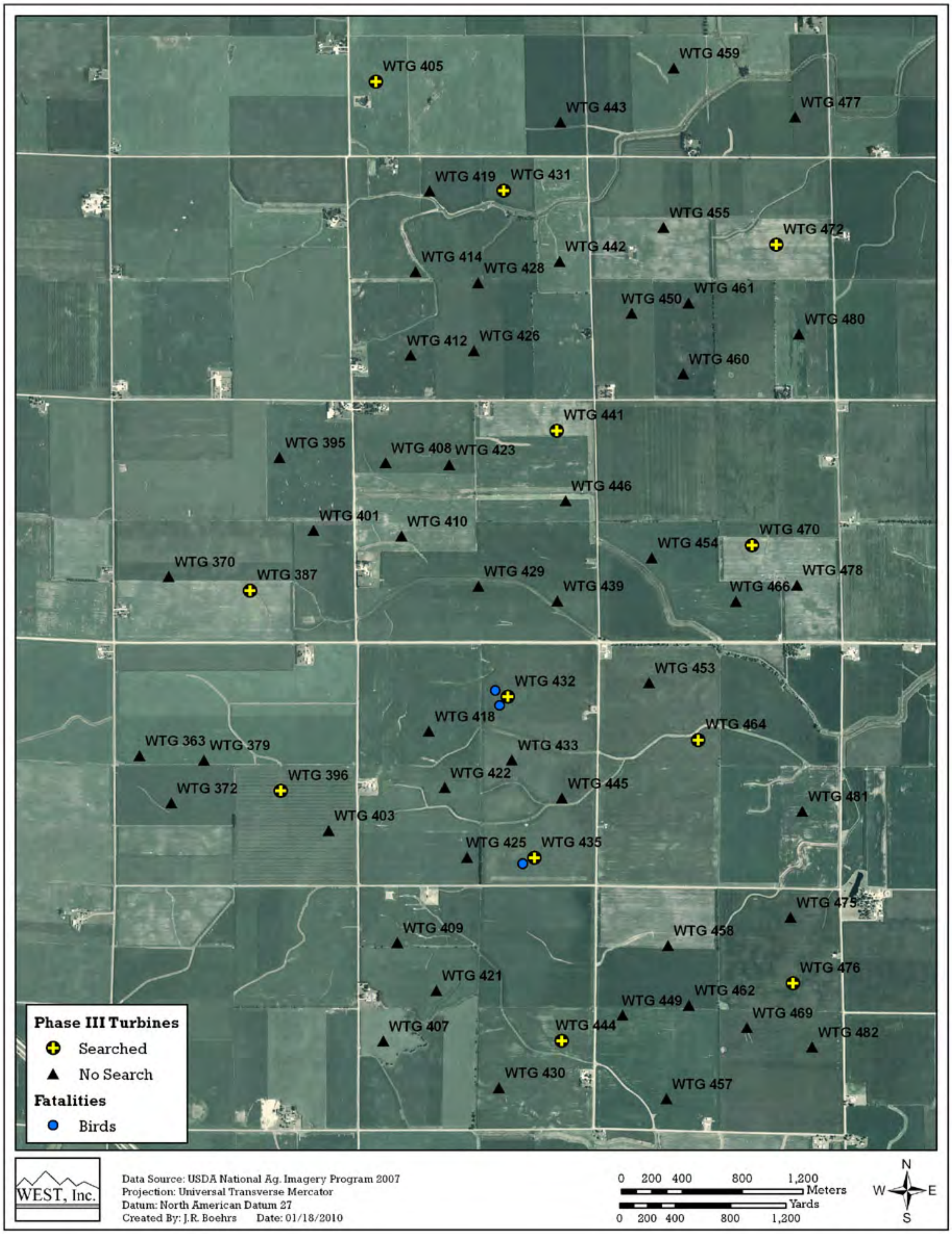

Figure 4. Location of bird casualties found at the Fowler Ridge III Wind-Energy Facility.

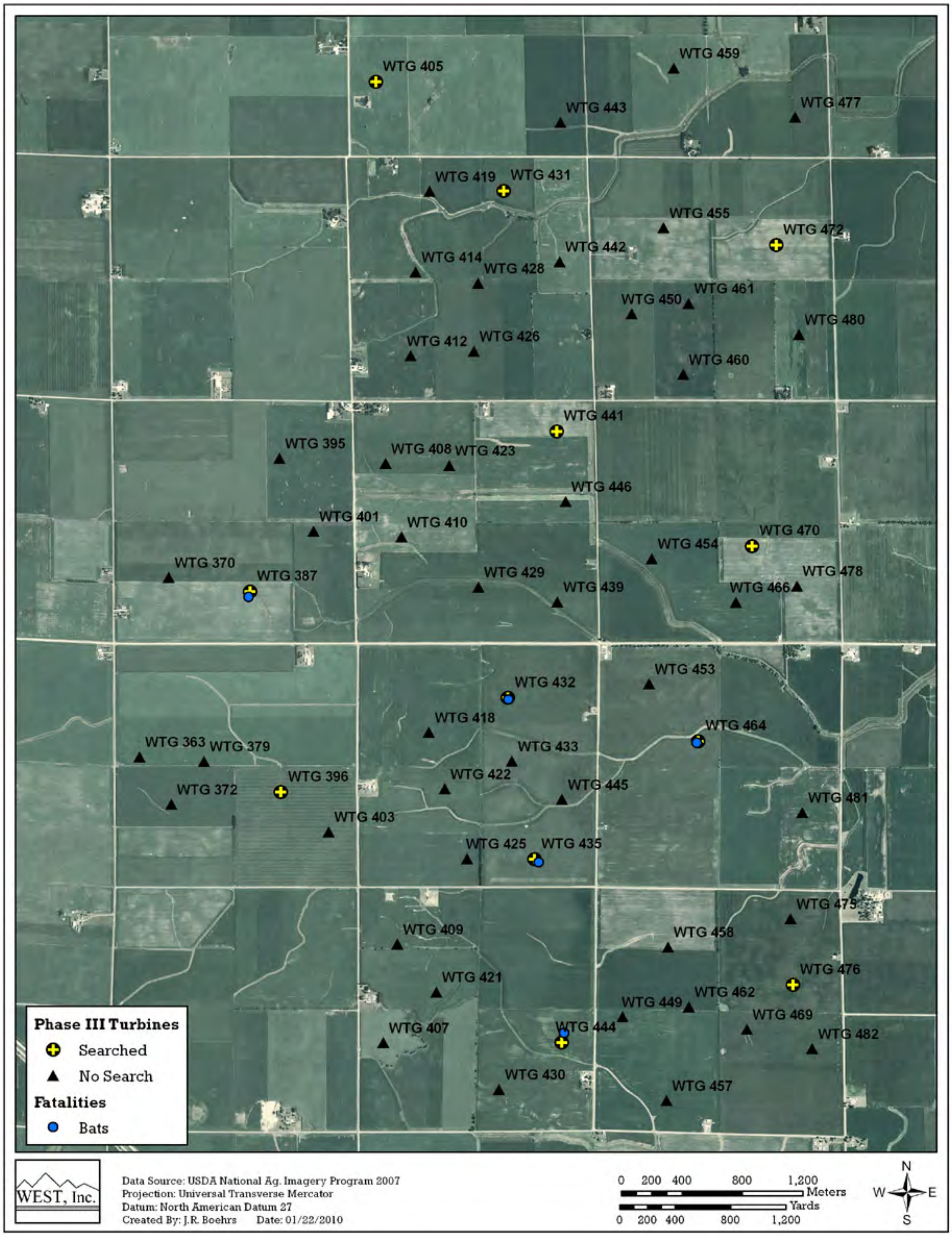

Figure 5. Location of bat casualties found at the Fowler Ridge III Wind-Energy Facility.

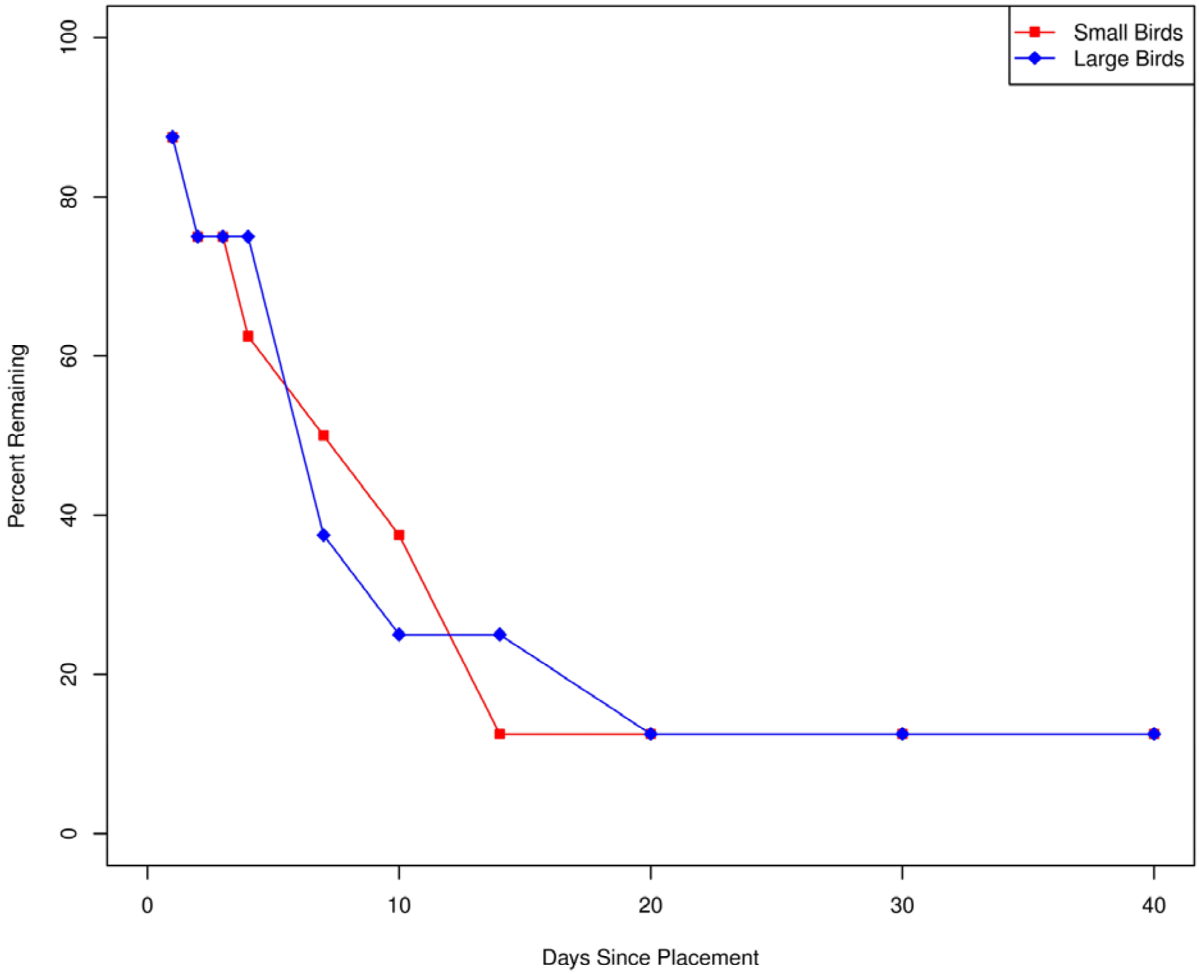

Figure 6. Scavenger removal rates for the Fowler III Wind Energy Facility during the April 2 to June 10, 2009 study period.

Appendix A - Bird and Bat Casualties Found at the Fowler Ridge III Wind Energy Facility, Benton County, Indiana, April 2–June 10, 2009

Appendix A - Bird and bat casualties found at the Fowler Ridge III Wind Energy Facility, Benton County, Indiana, April 2–June 10, 2009.

Date	Species	Turbine	Distance to Turbine	Carcass Condition	Scheduled/Incidental
Birds					
4/13/2009	unidentified large bird	432	88	scavenged	carcass search
4/22/2009	unidentified duck	435	89	scavenged	carcass search
4/30/2009	unidentified duck	432	76	scavenged	carcass search
Bats					
4/30/2009	hoary bat	432	16	intact	carcass search
4/30/2009	hoary bat	435	45	injured-released	carcass search
4/30/2009	big brown bat	464	16	intact	incidental find
5/26/2009	silver-haired bat	444	61	scavenged	carcass search
6/10/2009	eastern red bat	387	41	intact	carcass search