Bat Evaluation Monitoring Studies at the Fowler Ridge Wind Farm Benton County, Indiana

August 4 – October 14, 2014

Prepared for:

Fowler Ridge Wind Farm

Prepared by:

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NATURAL RESOURCES ◆ SCIENTIFIC SOLUTIONS

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EXECUTIVE SUMMARY

The Fowler Ridge Wind Farm (FRWF) collectively includes Fowler Ridge Wind Farm LLC, Fowler Ridge II Wind Farm LLC, Fowler Ridge III Wind Farm LLC, and Fowler Ridge Wind Farm IV LLC. The FRWF currently consists of 355 wind turbines in three phases in Benton County, Indiana. A post-construction casualty study of bats was conducted by Western EcoSystems Technology, Inc. (WEST) within Phases I and III in 2009. During that study period, an Indiana bat carcass was found. The FRWF worked with the USFWS and developed a Habitat Conservation Plan for the Indiana bat designed to minimize Indiana bat casualties. FRWF received an Incidental Take Permit for Indiana bats in March of 2014 (TE95012A-0). FRWF contracted with WEST to complete monitoring of bat carcasses in 2014 per the terms of the HCP, with the goal of determining if the level of Indiana bat mortality was within authorized limits.

The primary objective of the 2014 monitoring was to determine if the FRWF's approved minimization measures resulted in a 50% or greater reduction in mortality compared to turbines that operated normally in 2010. The 2014 casualty study occurred during the fall (August 1 – October 15) migration period for Indiana bats. Casualty searches were completed twice per week on roads and gravel pads of 118 turbines from August 4 – October 14, 2014. Personnel trained in proper search techniques conducted the carcass searches. Searches occurred along transects within each search plot. Searchers walked at a rate of approximately 45 to 60 meters (m) per minute (about 148 to 197 feet [ft] per minute) along each transect looking for bat carcasses. Transects were spaced at approximately 5 m (16 ft) intervals on road and pads, and searchers scanned the area on both sides out to approximately 2.5 m (about eight ft) for casualties as they walked each transect. Bias trials of searcher efficiency and carcass removal rates were conducted.

A total of 116 bat carcasses were found in 2014. Similar to previous years of monitoring, the most commonly found bat species were eastern red bats, silver-haired bats, and hoary bats. One big brown bat and one tri-colored bat were also found. No Indiana bat carcasses or other *Myotis* species were found.

Bat fatality rates were calculated based on number of carcasses found, the results of bias trials, and adjustments for bats that did not fall on roads and pads. Bat fatality rates in 2014 were estimated to be 3.84 bat fatalities/MW/study period (90% CI 3.05 – 4.82), which was 78% lower than casualty estimates at turbines operating normally in 2010. The results of monitoring during 2014 provide evidence that operational strategies exceeded the objective of reducing bat casualty rates by 50% compared to casualty estimates from turbines in normal operation modes in 2010. Within season adjustments to minimization strategies were not required in 2014 because bat fatality rates were well below adaptive management thresholds.

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INTRODUCTION AND BACKGROUND

The Fowler Ridge Wind Farm (FRWF) collectively includes Fowler Ridge Wind Farm LLC, Fowler Ridge II Wind Farm LLC, Fowler Ridge III Wind Farm LLC, and Fowler Ridge Wind Farm IV LLC. The FRWF currently consists of 355 wind turbines in three phases in Benton County, Indiana. A post-construction casualty study of bats was conducted by Western EcoSystems Technology, Inc. (WEST) within Phases I and III in 2009 (Johnson et al. 2010a, 2010b). During that study period, an Indiana bat carcass was found. Subsequent studies were conducted in 2010, 2011, 2012 and 2013 (Good et al. 2011, 2012, 2013, and 2014) under Scientific Research and Recovery Permits (TE15075A in 2010, TE15075A-2 in 2011, and TE73598A-0 in 2012 and 2013) within Phases I, II, and III. The results of research at the FRWF in 2010 and 2011 were used by the FRWF to design an operational monitoring strategy designed to reduce Indiana bat casualty rates. The FRWF worked with the US Fish and Wildlife Service (USFWS) and developed a Habitat Conservation Plan (HCP) for the Indiana bat designed to minimize Indiana bat casualties by feathering blades when winds were at 5.0 m/s or lower. FRWF received an Incidental Take Permit for Indiana bats in March of 2014 (TE95012A-0) based on the HCP. FRWF contracted with WEST to complete monitoring of bat carcasses in 2014 per the terms of the HCP and TE95012A-0. The primary objective of the 2014 monitoring was to determine if the FRWF's approved minimization measures resulted in a 50% or greater reduction in bat mortality compared to turbines that operated normally in 2010.

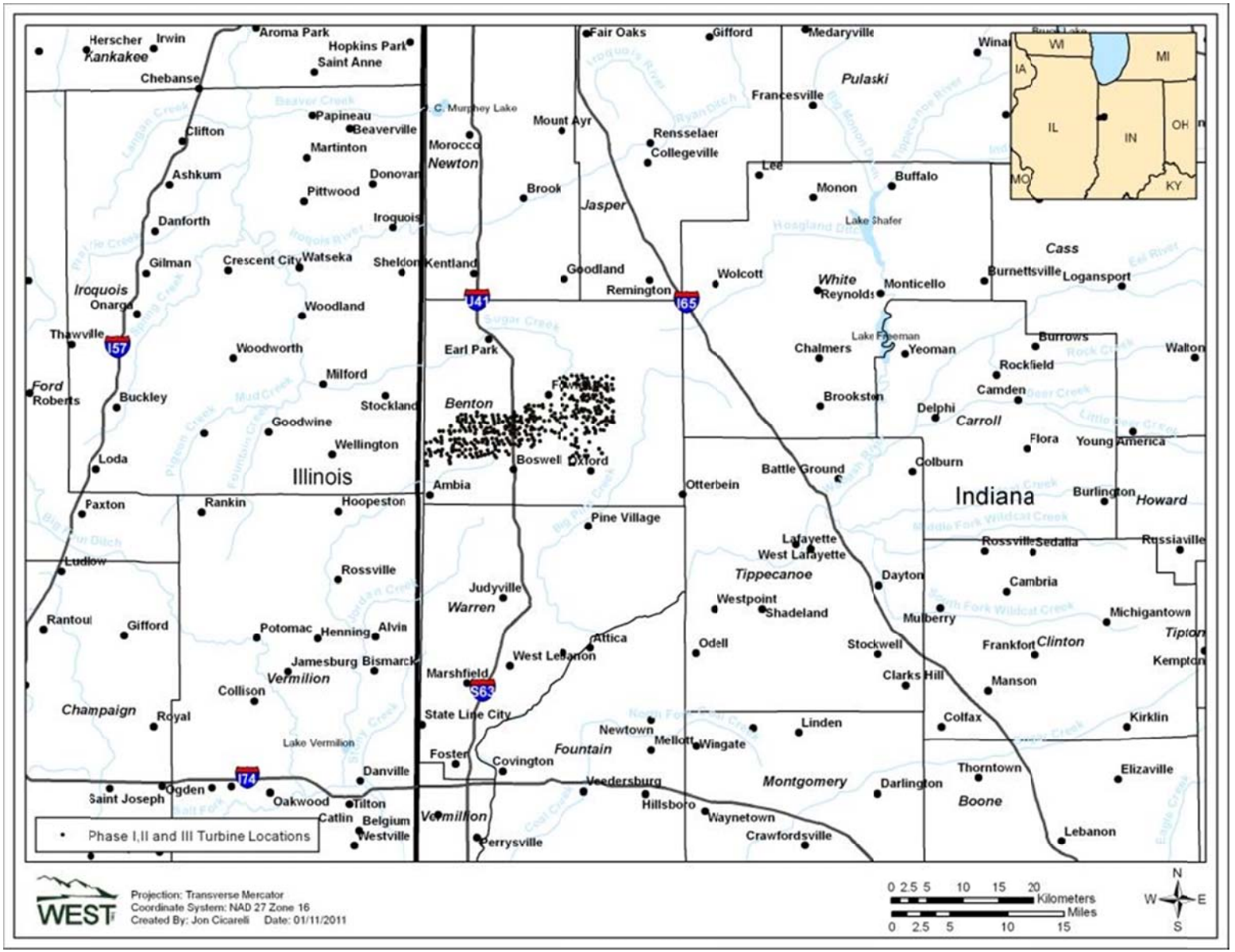

Figure 1. Location of the Fowler Ridge Wind Farm, Phases I, II and III.

STUDY AREA

The FRWF currently has a total energy capacity of 600 megawatts (MW). Phase I consists of 122 Vestas V82 1.65-MW turbines and 40 Clipper C96 2.5-MW turbines for a total of 301 MW of energy capacity. Phase II consists of 133 1.5-MW General Electric (GE) SLE turbines with a total capacity of 199.5 MW. Phase III consists of 60 Vestas V82 1.65-MW turbines (99 total MW of capacity). The three turbine types varied in size (Table 1).

Table 1. Turbine characteristics at the Fowler Ridge Wind Farm.

Turbine Model	MW	Turbine Height (meters)	Rotor Diameter (meters)	Standard cut-in speed (meters/second)
GE SLE	1.5	80	77	3.5
Vestas V82	1.65	80	82	3.5
Clipper C96	2.5	80	96	3.5

Phases I and III were constructed in 2008 and became operational during January of 2009. Phase II was constructed in 2009 and became operational by December 31, 2009. Phase IV has not been constructed at the time of this report.

The FRWF is located in western Indiana in Benton County (Figure 1). The wind energy facility lies within the Tipton Tall Plain physiographic region that includes much of central Indiana and lies within the Grand Prairie Natural Region that includes a small section of north central Indiana (Whitaker and Mumford 2009). The topography of the FRWF is mostly flat to slightly rolling and there are no hills, ridges, or other areas of starkly elevated topography (Figure 2). Elevations in the project area range from approximately 700-800 feet (ft; 213-244 meters [m]). Soils in the FRWF are various combinations of silt loam, clay loam, loam, silty clay loam, sandy loams and sandy clays (US Department of Agriculture Natural Resources Conservation Service [USDA-NRCS] 2006). Much of the area is classified as prime farmland based on soil type.

The FRWF is dominated by tilled agriculture with corn (*Zea mays*) and soybeans (*Glycine max*) being the dominant crops. Of the roughly 59,000 acres (about 92 square miles [mi^2]) within one half-mile (0.80 kilometers [km]) of turbine locations, row crops comprise about 93% of the land use for the study area (Homer et al. 2004; Table 2). After tilled agriculture, the next most common land uses within the FRWF are developed areas (e.g., houses and buildings), which compose 5.3% of the total, and pastures/hayfields, which compose 1.7% of the total area. There are 23.9 acres (0.04 mi^2) of grasslands, which compose less than 0.1% of the FRWF. Grasslands in the study area are limited primarily to strips along drainages, railroad rights-of-way (ROWs), and ROWs along county and state roads. There are also a few grass-lined waterways within cultivated fields in the study area. Trees in the study area occur at homesteads, along some of the drainages and fencerows, and within some small, isolated woodlots. Forested areas are rare within the study area based on 2001 data (Homer et al. 2004), and the 291.11 acres (0.45 mi^2) of forest compose 0.5% of the total area. Small amounts of barren ground, open water, and woody wetlands are also present.

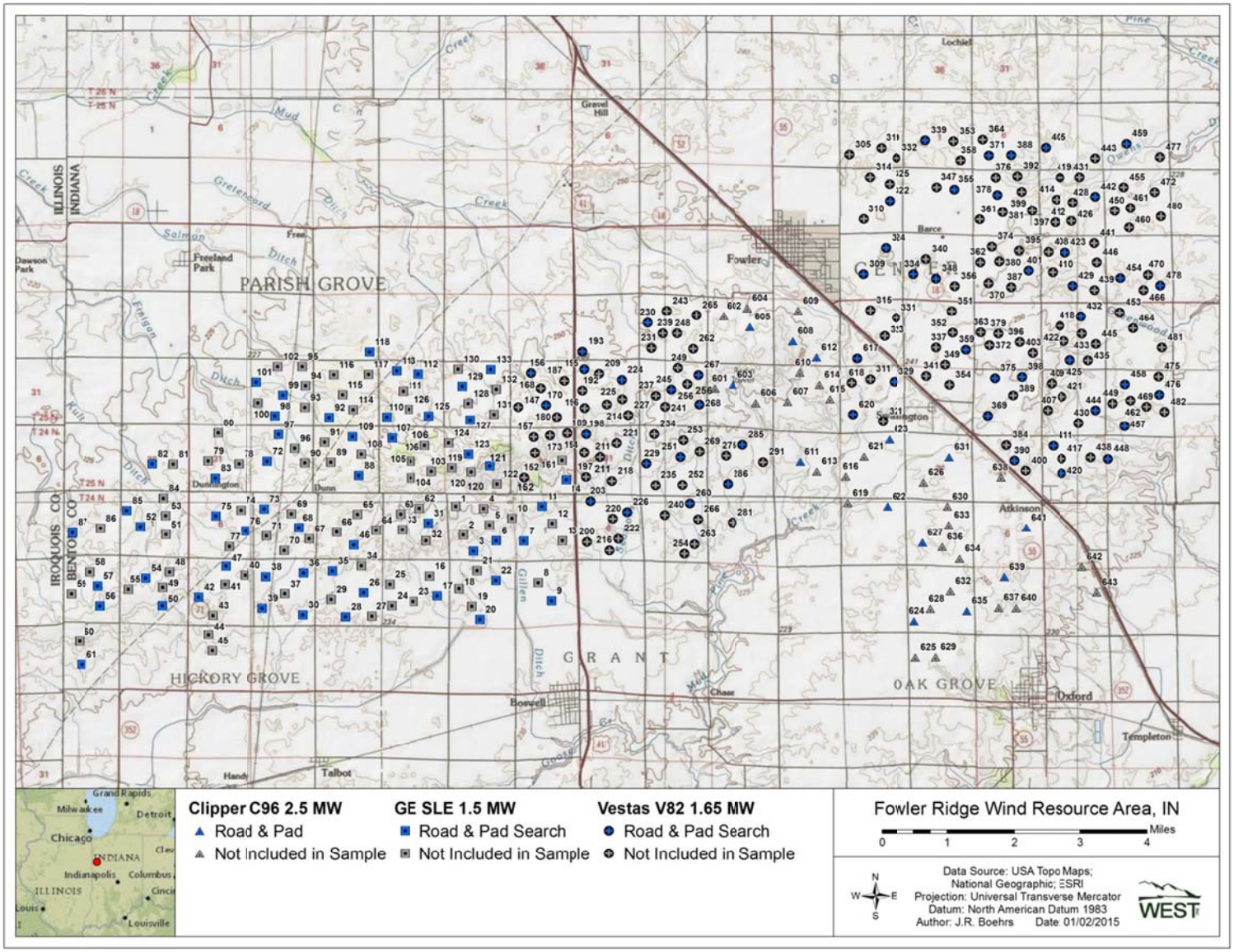

Figure 2. Elevation and topography of the Fowler Ridge Wind Farm (USGS 2011 – 2013).

Table 2. Land cover data within a half-mile of turbine locations within the Fowler Ridge Wind Farm (Homer et al. 2004).

Habitat Type	Acres	Percent Composition
Crops	54,611.24	92.5
Developed, Low Intensity	1,682.37	2.9
Developed, Open Space	1,347.93	2.3
Pasture/Hay	978.15	1.7
Deciduous Forest	291.90	0.5
Developed; Medium Intensity	53.65	0.1
Grassland	23.90	<0.1
Open Water	18.25	<0.1
Developed, High Intensity	16.40	<0.1
Barren	10.02	<0.1
Woody Wetlands	1.23	<0.1
Total	**59,035.05**	**100**

METHODS

Season

The 2014 casualty study occurred during fall from August 4 – October 14. This time period encompassed the fall migration period for Indiana bats, as outlined in the Draft Indiana Bat Recovery Plan (USFWS 2007), the period of highest bat mortality at the FRWF (Good et al. 2011, 2012), and the period in which previous Indiana bat carcasses occurred at the FRWF.

Search Plot and Sample Size

The FRWF is comprised of 355 turbines. One-hundred-eighteen turbines (about 33%) were sampled during the study (Figure 2). The same turbines sampled in 2012, 2013 were searched in 2014, with one exception. Turbine 609 was switched with turbine 608 because turbine 609 was not operating during the study period. Carcass searches were conducted along access roads and turbine pads within 80 m (262 ft) of the turbine.

Search Frequency

Turbines were searched twice weekly. The search interval was based on mean carcass removal times of 5.8 days observed during monitoring at FRWF in 2013 (Good et al. 2014).

Turbine Operation Schedule

Turbine cut-in speeds were raised to 5.0 m/s at the FRWF from August 1 – October 15. Turbine operational parameters were set so that the rotation of the turbine rotors below cut-in wind speed was feathered. Increasing cut-in speed and feathering of turbine blades below cut-in wind speed were implemented on a nightly basis from sunset to sunrise, adjusted for sunset/sunrise times weekly. Turbines were monitored and controlled based on wind speed on an individual basis (i.e., the entire facility did not alter cut-in speed at the same time, rather operational changes were based on wind speed conditions specific to each turbine). Turbines began operating under normal conditions when the 5- to 10-minute rolling average wind speed was

above 5.0 m/s; turbines were feathered again if the 5- to 10-minute rolling average wind speed dropped below 5.0 m/s during the course of the night.

Field Methods

Casualty Searches

Observers trained in proper search techniques conducted the carcass searches. Searches occurred along transects on roads and pads within each search plot within 80 m of turbines. Searchers walked at a rate of approximately 45 to 60 m per minute (about 148 to 197 ft per minute) along each transect looking for bat carcasses. Transects were spaced at approximately 5 m (16 ft) intervals, and searchers scanned the area on both side sides out to approximately 2.5 m (about eight ft) for casualties as they walked each transect. All bat carcasses were recorded and collected. Bird carcasses were recorded, but left in the field. Searches began after 0700 hours (H) each morning, and were completed by early afternoon.

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

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

Tissue and hair samples were collected from all dead bats and delivered to the USFWS Bloomington Field Office. A copy of the data sheet for each carcass was maintained, bagged, and kept with the carcass at all times. For all casualties found, data recorded included: species, sex and age when possible, turbine identification number, date and time collected, global positioning system (GPS) location, condition (live, intact, scavenged, feather spot), and distance from turbine, as well as any comments that may indicate cause of death. All bird and bat carcasses located were photographed as found. Estimated time since death for bats was also recorded. Criteria used to determine time since death can be found in Appendix A.

Casualties found outside the formal search area by observers or by FRWF personnel were treated following the above protocol as closely as possible. Casualties found in non-search areas (e.g., near a turbine not included in the sample of search area) were coded as incidental discoveries, collected, and documented in a similar fashion as those found during standard searches. Incidental carcasses found in non-search areas were not included in the analysis. In addition to carcasses, all injured bats and birds observed in search plots were recorded and treated as a casualty for the purpose of the analyses.

Field Bias Trials

Searcher efficiency and removal of carcasses by scavengers was quantified to adjust the estimate of total bat fatalities for detection bias. Bias trials were conducted throughout the entire study period. Fifty bats were used for searcher efficiency trials. When possible freshly killed bats conclusively identified as non-*Myotis* or non- *Nicticeius humeralis* were used for searcher efficiency and carcass removal trials. Due to the lack of freshly killed (intact) bats available for the initial trial effort, trial bat carcasses were supplemented by frozen non-*Myotis* bat carcasses supplied by Indiana State University. Trial bats were placed throughout the study session by a biologists not involved in the carcass search effort at a particular set of turbines, and were placed within any given turbine's searchable area. Searchers had no knowledge of the number, placement, or timing of carcasses at turbines. Data recorded for each trial carcass prior to placement included date of placement, species, turbine number, and the distance to and direction from the turbine. Carcasses were identified as bias trial carcasses through the placement of small, indistinct black zip ties on the bats' wings. Bat carcasses were placed at varying intervals before scheduled searches on plots (i.e., a carcass may have been placed at a plot not scheduled to be searched for four days). Carcasses were left in the field for up to 24 days, resulting in searchers having six chances of finding a carcass that lasted the full 24 days. The first day the carcass was discovered by the searcher was recorded to estimate the overall probability that a carcass was available and detected. Sixty-one bat carcasses were left in the field, 26% of which were fresh, and checked on days one, two, four, six, eight, 10, 12, 18, and 24 to calculate average carcass removal rates. Day one was defined as the 1st day a carcass was placed.

Statistical Analysis

Bat Mortality Estimation

Estimates of facility-related bat mortality were calculated based on:

1) Observed number of bat carcasses found during standardized searches during the monitoring period;
2) Non-removal rates combined with searcher efficiency, expressed as the estimated average probability a bat carcass is expected to remain in search areas and be available for detection and was detected by the observers during combined bias trials; and
3) The area adjustment factor for bat carcasses landing outside of searched roads and pads.

Carcasses found on a scheduled search plot were included in the casualty analysis, regardless of whether they were found during a scheduled search or incidentally at some other time. We assumed that all carcasses found incidentally on scheduled search plots would have been found at the next search if they had not been found incidentally. Those carcasses found during searches but not within the search area were not included in casualty estimates.

The probability of carcass availability and detection ($\hat{\pi}$) was calculated based on the results of combined bias trials. Carcasses were placed in the field throughout the search interval and left

until they were either found by searchers or removed by some means such as scavenging. The ratio of the number found to the number placed was then calculated and used as an empirical estimate of the probability of availability and detection. This method was used during previous study years at the FRWF and was used to provide a comparable casualty estimate.

A correction factor (r) of 6.56 was used to adjust for carcasses that likely occurred outside of searched roads and pads, to determine total estimated bat mortality during the fall migration period. This area adjustment factor was an average of the road and pad correction factors from 2010 and 2011 at the FRWF (Good et al. 2011, 2012).

The adjusted estimate for the number of fatalities per turbine was calculated as follows:

$$m = \frac{(observed\ fatalities)}{(number\ of\ search\ plots) * \hat{\pi}} * r$$

Mean carcass removal time ($\bar{t}$) was calculated as the average length of time a carcass remained in the study area before it is removed:

$$\bar{t} = \frac{\sum_{j=1}^{s} t_j}{s - s_c}$$

Definition of Variables

The following variables were used to calculate carcass removal rates:

- 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 24 days
- t_j the time (in days) carcass j 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

Between Years Comparisons

Percent change in casualty rates between 2014 and the baseline year (2010) was calculated and compared to the anticipated 50% reduction in casualty rates due to applied minimization measures.

Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC) measures were implemented at all stages of the study, including in the field, during data entry and analysis, and report writing. Following field surveys, observers were responsible for reviewing data for completeness, accuracy, and

legibility. A sample of records from an electronic database was compared to the raw data forms and any errors detected were corrected. Irregular codes or data suspected as questionable were discussed with the observer and/or project manager. Errors, omissions, or problems identified in later stages of analysis were traced back to the original data entry, and appropriate changes in all steps were made. A Microsoft® ACCESS database was developed to store, organize, and retrieve survey data. Data were keyed into the electronic database using a pre-defined format to facilitate subsequent QA/QC and data analysis. All data forms and electronic data files were retained for reference.

RESULTS

The following sections contain the results of studies conducted under permit TE96012A-0. Per the requirements of this permit, information regarding the date, locations, and species of bats encountered can be found in Appendix B. Raw data forms can be found in Appendix C.

Bat and Bird Carcasses

A total of 2,427 twice-weekly surveys were conducted on roads and pads across 118 turbines from August 4 – October 14, 2014. Overall, 116 bat carcasses were found, with 99 carcasses found during scheduled searches and an additional 17 bat carcasses found incidentally at turbines between August 4 – October 14, 2014. The incidental bat carcasses were not found on search areas and were not included in the casualty estimates (Table 3; Appendix B).

Overall, 16 bird carcasses were found during the study period, with 13 carcasses found during scheduled searches and 3 incidental finds (Table 3).

Species Composition

The most commonly found bat species during the 2014 study were eastern red bat (*Lasiurus borealis*; 49 carcasses, 42.2% of carcasses), followed by silver-haired bat (*Lasionycteris noctivagans;* 40 carcasses, 34.5%), and hoary bat (*Lasiurus cinereus*; 25 carcasses, 21.6%). Two other species were found, including big brown bat (*Eptesicus fuscus;* 1 carcass, 0.9%) and tricolored bat (*Perimyotis subflavus*; 1 carcass, 0.9%). No Indiana bat carcasses or *Myotis* carcasses were found during the 2014 study (Table 3).

Table 3. Total number of bird and bat carcasses and the percent composition of carcasses found during post-construction monitoring at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Species	Carcasses during Scheduled Searches		Incidental carcasses at Search Plots*		Other Incidentals**		Total	
	Total	% Comp.	Total	% Comp.	Total	% Comp.	Total	% Comp.
Birds								
mourning dove	3	23.1	0	0	1	33.3	4	25.0
purple martin	2	15.4	0	0	0	0.0	2	12.5
common grackle	1	7.7	0	0	1	33.3	2	12.5

Table 3. Total number of bird and bat carcasses and the percent composition of carcasses found during post-construction monitoring at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Species	Carcasses during Scheduled Searches		Incidental carcasses at Search Plots*		Other Incidentals**		Total	
	Total	% Comp.	Total	% Comp.	Total	% Comp.	Total	% Comp.
Tennessee warbler	1	7.7	0	0	1	33.3	2	12.5
barn swallow	1	7.7	0	0	0	0.0	1	6.3
ruby-crowned kinglet	1	7.7	0	0	0	0.0	1	6.3
unidentified icterid	1	7.7	0	0	0	0.0	1	6.3
unidentified sparrow	1	7.7	0	0	0	0.0	1	6.3
unidentified warbler	1	7.7	0	0	0	0.0	1	6.3
yellow-billed cuckoo	1	7.7	0	0	0	0.0	1	6.3
Bird Total	**13**	**100.0**	**0**	**0**	**3**	**100.0**	**16**	**100.0**
Bats								
eastern red bat	45	45.5	0	0	4	23.5	49	42.2
silver-haired bat	35	35.4	0	0	5	29.4	40	34.5
hoary bat	17	17.2	0	0	8	47.1	25	21.6
big brown bat	1	1.0	0	0	0	0.0	1	0.9
tricolored bat	1	1.0	0	0	0	0.0	1	0.9
Bat Total	**99**	**100**	**0**	**0**	**17**	**100**	**116**	**100**

*Carcasses found incidentally on turbine search plots were included in analyses.
**Carcasses found that were estimated to have been killed prior to the start of the study, or carcasses that were found outside of plot boundaries. These carcasses were not included in the analysis.

The sixteen bird carcasses found during the survey represent 10 individual bird species (Table 3). No bird species listed as threatened or endangered under the State of Indiana (IDNR, INHDC 2013) or federal endangered species acts (ESA 1973, USFWS 2013) were found.

Estimated Time since Death

Most bat carcasses were estimated to have been killed the previous night (46.5%) or two to three days before the scheduled search (45.5%; Table 4a). Most bird carcasses were estimated to have been killed two to three days before the scheduled search (38.5%) or four to seven days before the scheduled search (30.8%; Table 4b).

Table 4a. Estimated time since death of bat carcasses at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Estimated Time Since Death	Number of Carcasses	Percent Composition
Bats		
last night	46	46.5
2-3 days	45	45.5
4-7 days	3	3.0
7-14 days	2	2.0
>2 weeks	2	2.0
>month	1	1.0
unknown	0	0.0

[a:] Estimated time since death criteria described in Appendix A.

Table 4b. Estimated time since death of bird carcasses at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Estimated Time Since Death	Number of Carcasses	Percent Composition
Birds		
last night	2	15.4
2-3 days	5	38.5
4-7 days	4	30.8
7-14 days	0	0.0
>2 weeks	2	15.4
>month	0	0.0
unknown	0	0.0

[a:] Estimated time since death criteria described in Appendix A.

Timing of Bat Carcasses

Bat casualties occurred throughout the study period (Figure 3). The majority of bat causalities were found near the end August (08/28/14) to the middle of September (09/16/14; Figure 3). A low number of carcasses were found in early October and numbers continued to decrease through the end of the study.

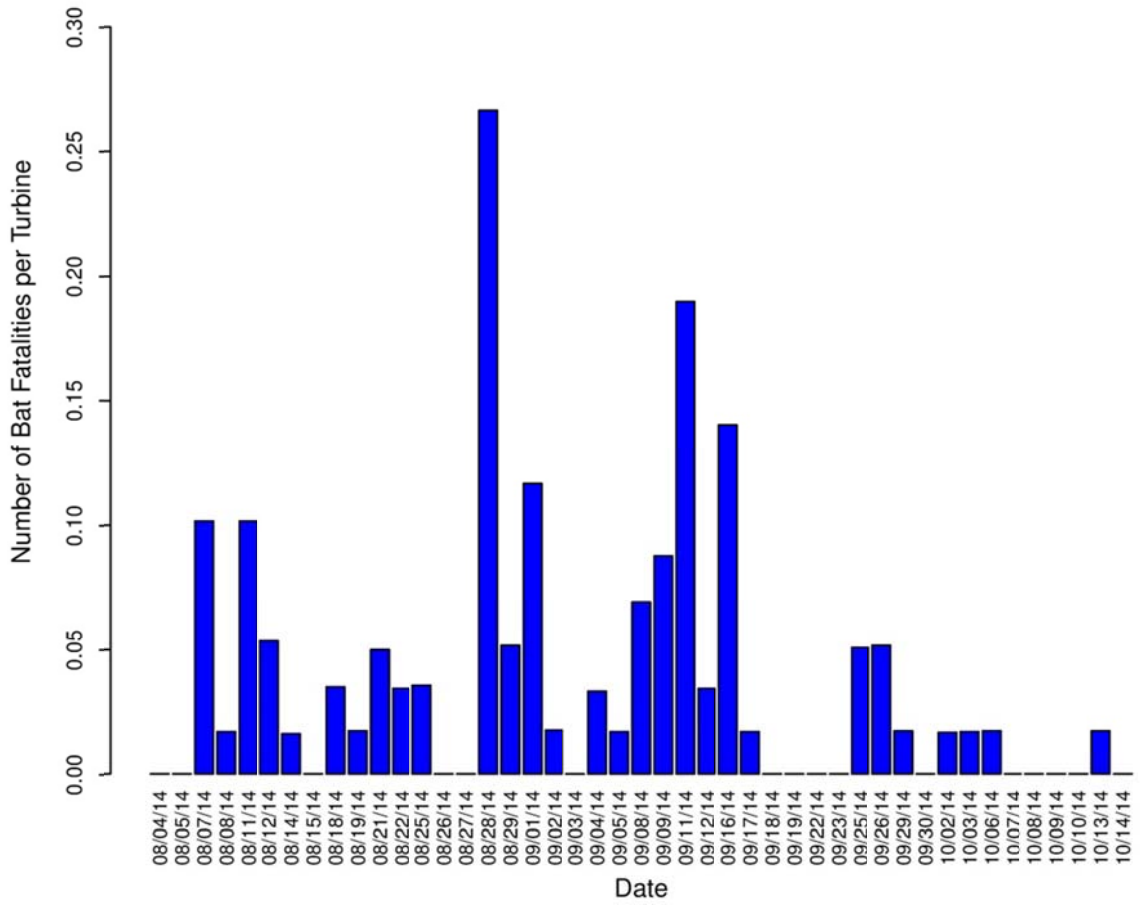

Figure 3. Timing of bat carcasses per turbine found during scheduled searches or incidentally on turbine search plots at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Distribution of Bat Casualties

A total of 96% of bat carcasses were found within 50 m (164 ft) of turbines, with the highest percentage (41.4%) of carcasses found between 0 – 10 m (0 – 33 ft), followed by 18.2% of bat carcasses each found between 20 – 30 m (68 – 98 ft) and 16.2 % found between 30 – 40 m (98-131) from turbines (Table 5, Figure 4). This was a function of the amount of searchable area present within varying distances of turbines as road and pad comprise a higher percentage of area in each distance band closer to turbines.

Table 5. Distribution of distances from turbines of bat casualties found during scheduled searches or incidentally on turbine search plots at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Distance to Turbine (m)	% Bat Casualties
0 to 10	41.4
10 to 20	14.1
20 to 30	18.2
30 to 40	16.2
40 to 50	6.1
50 to 60	1.0
60 to 70	3.0
70 to 80	0.0
80 to 90	0.0
>90	0.0

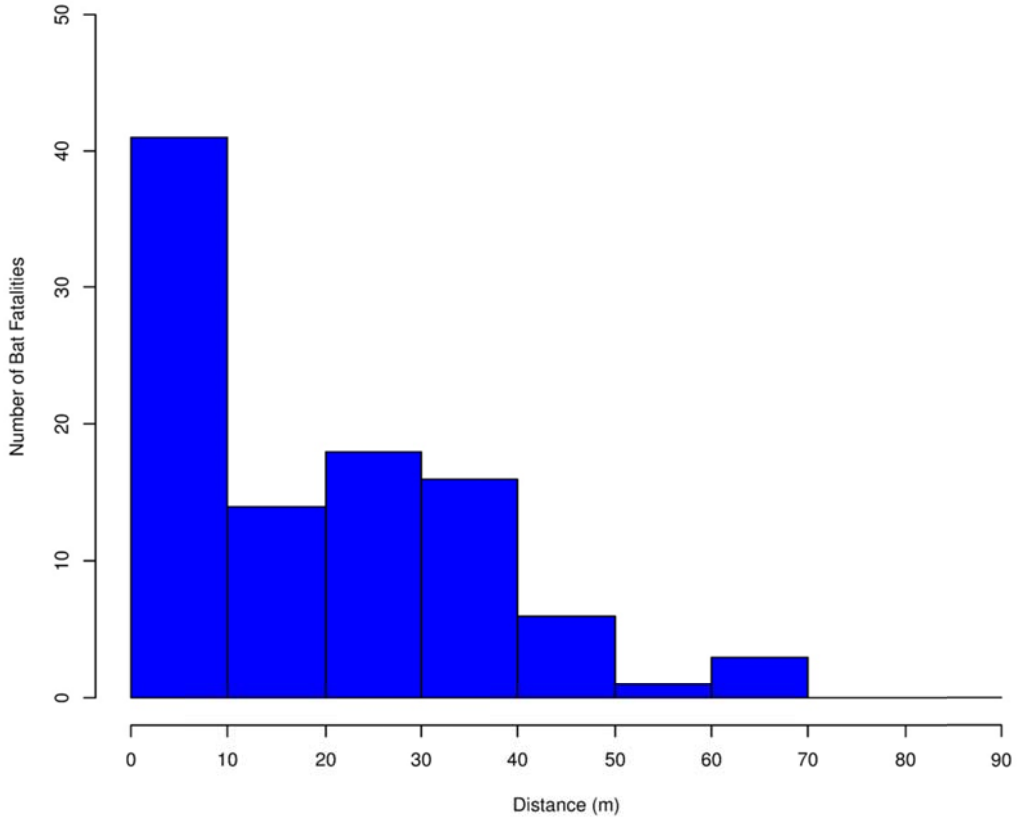

Figure 4. Distance of bat carcasses from the turbine found during scheduled searches or incidentally on turbine search plots at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Bat Carcasses by Turbine Location

The turbine with the highest density of bat casualties (4 casualties) was turbine number 459 (Vestas; Figure 5). Turbines 309, 369, 371, 458, 605, 608, 611 and 639 had the second highest density of bat casualties (3 casualties each; Figure 5). Of this group, turbines, 309, 369, 371, and 458 are Vestas, and turbines 605, 608, 611 and 639 are Clippers.

Bat carcasses occurred more frequently throughout the central and eastern portions of the FRWF (Vestas and Clipper turbines), with the majority of casualties being found at Vestas and Clipper turbine locations (Figure 6). The highest density for observed fatality rates occurred at the Clipper turbines with 25 carcasses on 13 searched turbines, for a rate of 1.92 observed bat carcasses per turbine. Vestas turbines had a rate of 1.04 observed bat carcasses per turbine, with 54 carcasses on 52 searched turbines. The lowest observed fatality rate was at the GE turbines with 0.38 bat carcasses per turbine (20 carcasses on 53 searched plots).

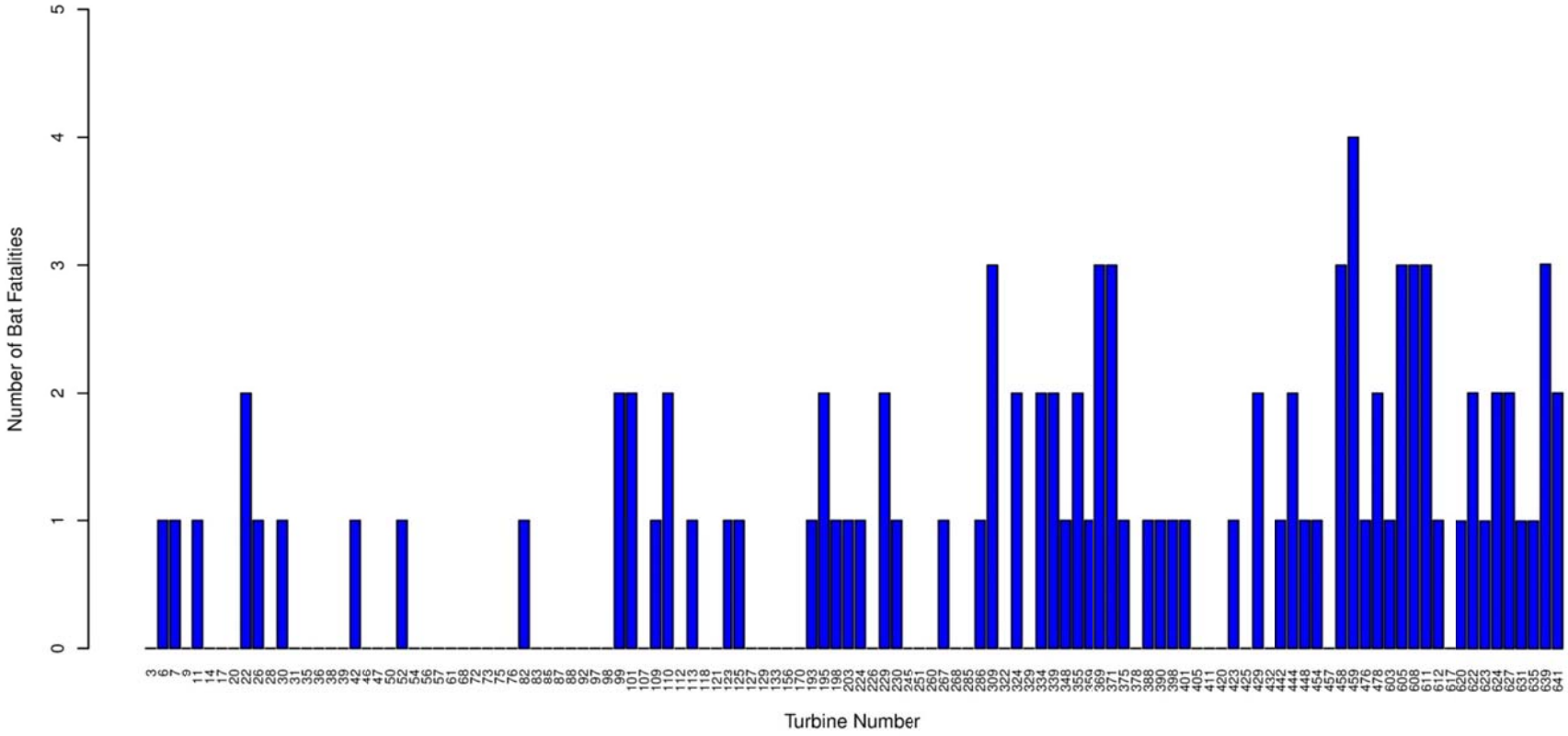

Figure 5. Number of bat carcasses by turbine found during scheduled searches or incidentally on turbine search plots at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

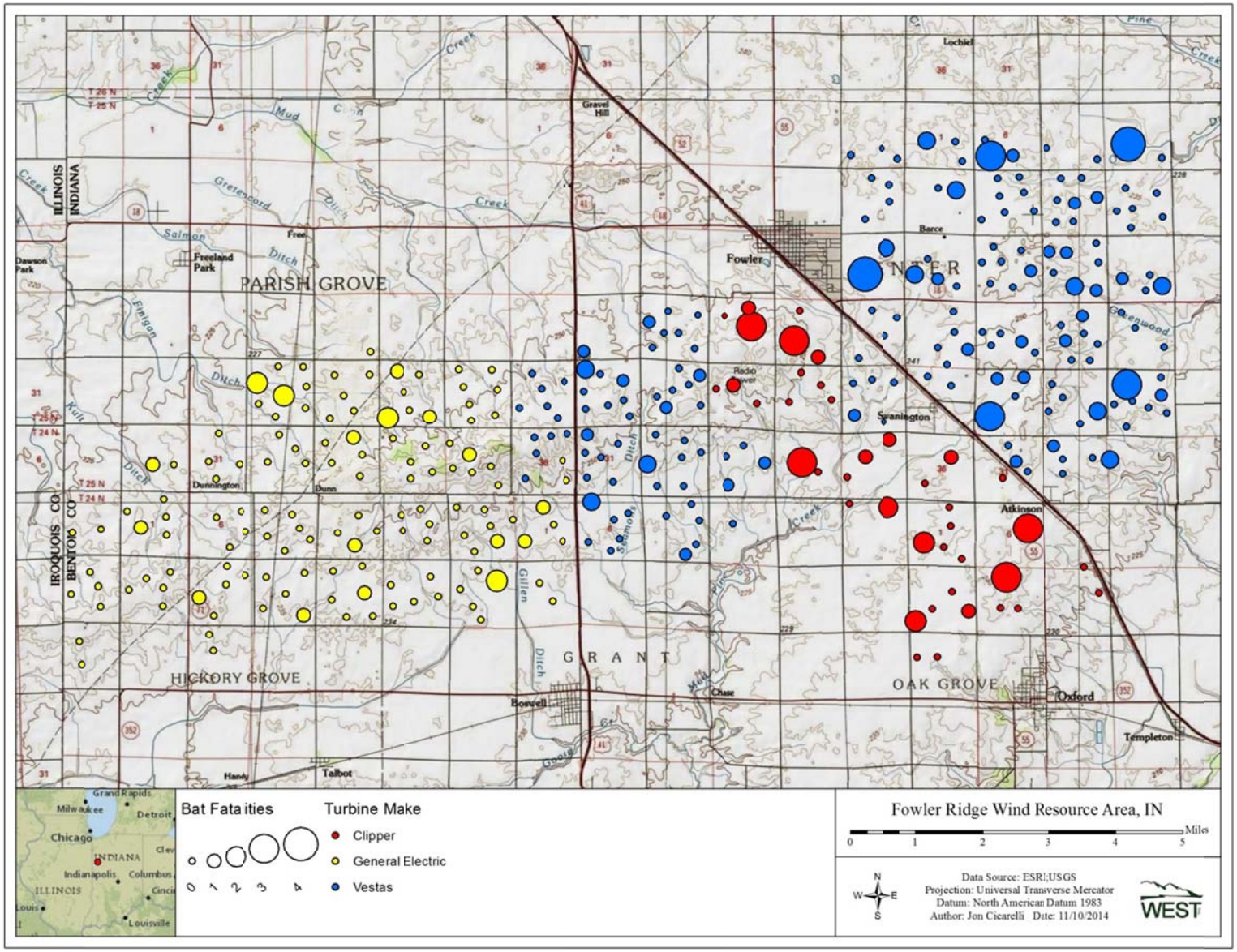

Figure 6. Location of all bat casualties found at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Bias Trials

Bias trials were conducted throughout the study period at five placement intervals. A total of 50 bat carcasses were placed prior to a scheduled search ranging from zero to four days prior to searches, and were used to calculate the overall probability that a bat carcass was available and detected (Table 6). Of the 50 trial carcasses placed, 39 were found at the next scheduled search (Table 6), with one additional bat that was found after multiple searches, resulting in an overall empirical pi searcher efficiency rate of 81% for a 3.5 day interval between searches (Table 7). The probability of available and detected carcasses for 2014 was higher when compared to 2013 (55.5%), 2012 (56.7%) and 2010 (51%) because searches were completed more frequently in 2014 compared to 2010, 2012, and 2013.

Table 6. Searcher efficiency based on empirical pi by time since death methodology for post-construction casualty monitoring at the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Number of Days Prior to Search	Number Placed	Number Found on Next Search	Total Found	Percent Found
0	10	8	9	90
1	10	8	8	80
2	10	8	8	80
3	10	8	8	80
4	10	7	7	70
Total	50	39	40	**80**

A total of 61 bats were used to measure carcasses removal rates. The average length of stay for bat carcasses in 2014 was 19.36 days. The carcass removal estimates for 2014 were similar to 2011 (15.1 days; Good et al. 2012), and longer than the estimate of 2013 (5.8 days; Good et al. 2014).

Adjusted Casualty Estimates

Seventeen bat casualties found were not included in analyses because carcasses were found outside of search plots (Appendix B). Of the remaining casualties, 99 were included in the casualty estimate, resulting in an observed casualty rate of 0.84 bats per turbine. The observed casualty rate was then divided by the empirical probability of availability and detection (0.81). The value was multiplied by the road and pad correction factor (6.56) to obtain the per turbine adjusted fatality estimate for each type of turbine. The adjusted casualty estimate for the 2014 study was 6.77 bat fatalities/turbine/study period (Table 7), or 3.84 bat fatalities/MW/study period (Table 8). Similar to previous years of study, more bat casualties were found on Clipper turbines compared to Vestas and GE (Table 8).

Table 7. Number of bat fatalities per turbine per study period for the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Estimator	Point Estimate	Standard Deviation	90% Confidence Interval	
			Lower Limit	Upper Limit
Area Adjustment	6.56	-	-	-
Casualties per turbine	0.84	0.10	0.68	1.01
Empirical pi	0.81	0.04	0.75	0.88
Adjusted number of fatalities per turbine	6.77	0.94	5.31	8.44

Table 8. Adjusted bat fatality estimates (Empirical Pi) for different turbine types within the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

	Adjusted Overall Fatality Estimate and 90% Confidence Intervals	
	Mean	CI
	# fatalities/turbine/study period	
GE	3.05	1.85 – 4.47
Clipper	15.53	8.55 – 23.57
Vestas	8.38	6.06 – 10.94
All Turbines	6.77	5.31 – 8.44
	# fatalities/MW/study period	
GE	2.03	1.24 – 2.98
Clipper	6.21	3.42 – 9.43
Vestas	5.08	3.67 – 6.63
All Turbines	3.84	3.05 – 4.82

Comparison to 2010 Casualty Estimates

Road and pad searches completed in 2010 at turbines in normal operation mode provide the most direct comparison of casualty estimates to the 2012, 2013 and 2014 estimates. Data collected in 2010 provide a baseline from which future casualty estimates can be compared. During 2010, 31.23 bat casualties/turbine/study period (90% confidence interval [CI] 18.77 – 48.94) were estimated from road and pad searches of 100 turbines in normal operation mode, after adjusting for bats falling outside of 40 m (Good et al. 2012). Point estimates of 2014 casualty estimates from turbines feathered until wind speeds reached 5.0 m/s were 78.3% lower than casualty estimates at turbines operating normally in 2010, with an estimated 6.77 bat casualties/turbine/study period (90% CI 5.31 – 8.44).

Uncertainty surrounding bat casualty rates was estimated using 90% confidence intervals. Casualty rates from 2014 were compared to the anticipated 50% reduction in casualty rates from the baseline year (2010) to determine the effectiveness of the applied minimization measures. There is statistical evidence to support a greater than 50% reduction in casualty rate from 2010 to 2012, 2013 and 2014 (Figure 7).

Within Season Adaptive Management

The Fowler HCP includes an active adaptive management approach that facilitates responsiveness in management actions based on results from annual take compliance monitoring to ensure permit compliance. Within-season adaptive management thresholds were calculated to serve as an early indicator if adjustments to minimization efforts may be necessary before the conclusion of the monitoring year. Per the HCP, within-season adaptive management thresholds were based on the predicted number of bat carcasses that would be found that would equal the upper quartile (i.e., 75th percentile) of estimated fall bat mortality in 2010 and 2011 at control turbines with minimization measures in place: 9.5 Indiana bats per year for the entire facility. Based on the species composition described within the HCP, a fatality rate of 16.7 bats per turbine per season would be needed to result in 9.5 Indiana bat fatalities.

The Fowler HCP prescribes a sampling approach utilizing roads and pads to calculate fatality estimates. Per the HCP, to determine the number of bat carcasses of all species found that would equate to the adaptive management threshold for within season Indiana bat mortality, bias correction factors (i.e., unsearched areas, scavenger removal, and carcass removal) from the previous year's monitoring results were applied to the 2014 rates.

Given the increase in search frequency from 2013 to 2014, we recalculated the probability of a carcass being available and detected for a 3 day search interval (0.72) and 4 day search interval (0.63) from the 2013 empirical pi bias trial data (Good et al. 2014). We averaged the probability of available and detected for the 3 and 4 day search interval to get the probability of available and detected for a 3.5 day search interval (0.67). We then used the maximum adjusted fatality rate given in the HCP (16.7 fatalities/turbine) and the road and pad area correction factor (6.56), and back calculated the adaptive management threshold for 2014: 1.7 bat carcasses found/turbine or a total of 203 bat carcasses.

Figure 8 illustrates the within-season tracking tool that was used to determine if adaptive management was necessary in 2014. The weekly 2014 estimated bat fatality rate shown in Figure 8 was an estimate calculated using the 2013 bias trial data. The final 2014 bat fatality estimate was based on 2014 bias trial results. Adaptive Management thresholds were not exceeded at any time during the study, and no changes to minimization efforts were required during 2014.

End of Season Indiana Bat Take Estimate

The estimated number of Indiana bat casualties that occurred during 2014 was calculated based on the overall estimated bat fatality rate during 2014 and the relative percent that Indiana bat carcasses comprised of all bat carcasses found during Fall in 2009, 2010, and 2011 (0.16%). The total number of bats estimated to have occurred as casualties in 2014 was calculated for each turbine type, and then summed to calculate the total estimate. A total of 4.08 (90% CL 3.21 – 5.10) Indiana bat casualties were estimated to have occurred in 2014, which is 50% lower than the 8.6 Indiana bats that were predicted to occur as casualties within the HCP after minimization. Per the terms of the HCP no changes to minimization efforts are required for 2015.

Table 9. Estimated number of Indiana bat casualties for different turbine types within the Fowler Ridge Wind Farm from August 4 to October 14, 2014.

Turbine Type	Casualties	Number of Turbines Searched	Observed fatalities per turbine	pi hat	Area adjustment	Adjusted Fatality Estimates (Bats / Turbine)	Total Turbines	Estimated Number of Bat Casualties by Turbine Type	Estimated Number of Indiana Bat Casualties by Turbine Type
Vestas	54	52	1.04	0.81	6.56	8.38	182	1525.95	2.44
Clipper	25	13	1.92	0.81	6.56	15.53	40	621.065	0.99
GE	20	53	0.38	0.81	6.56	3.05	133	405.21	0.64

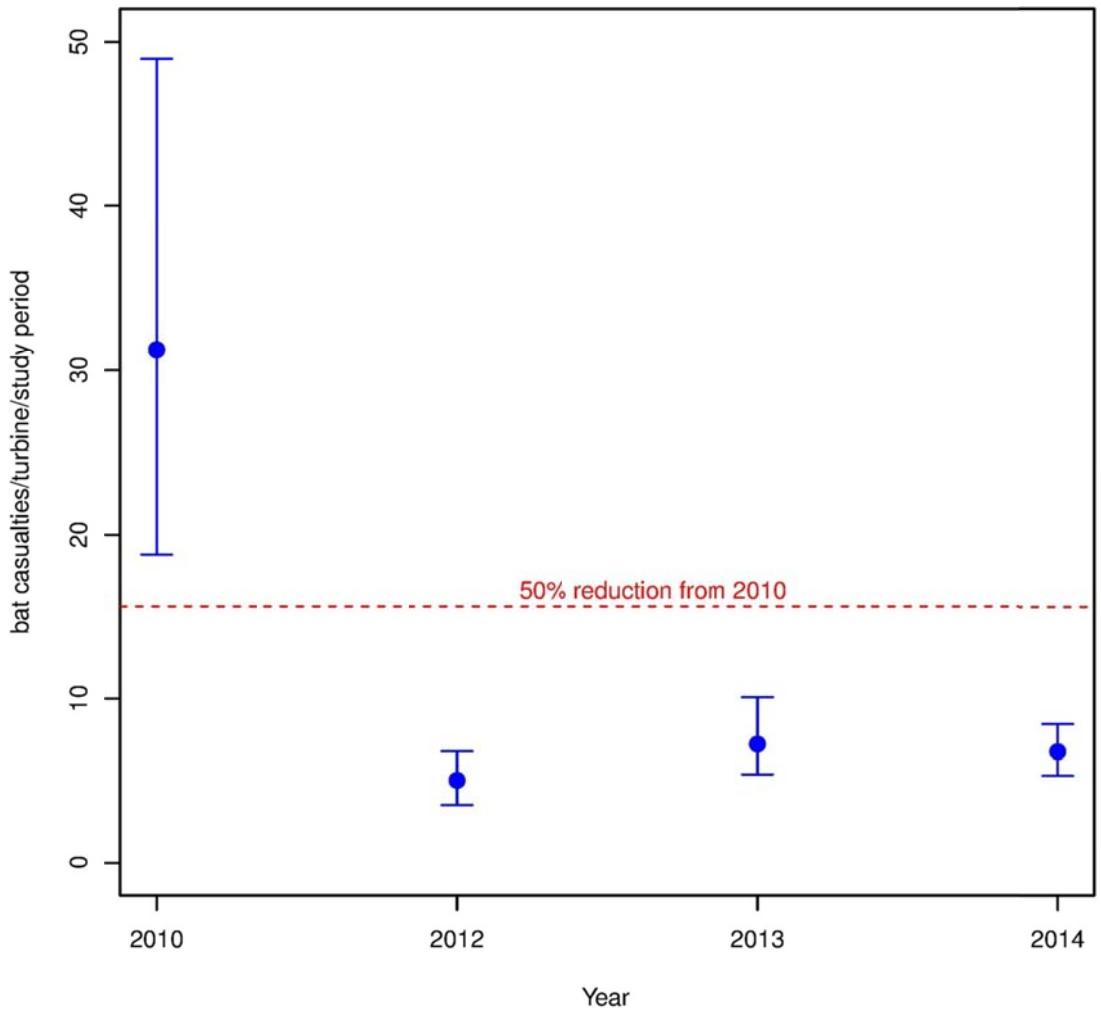

Figure 7. A comparison of estimated bat casualty rates and 90% confidence intervals for the Fowler Ridge Wind Farm. The 2010 estimate represents turbines operating at manufacturer cut-in speeds. The 2012, 2013 and 2014 estimates represent data collected at turbines feathered below 5.0 m/s. The red dotted line represents a 50% reduction in bat casualty rates compared to the 2010 point estimate.

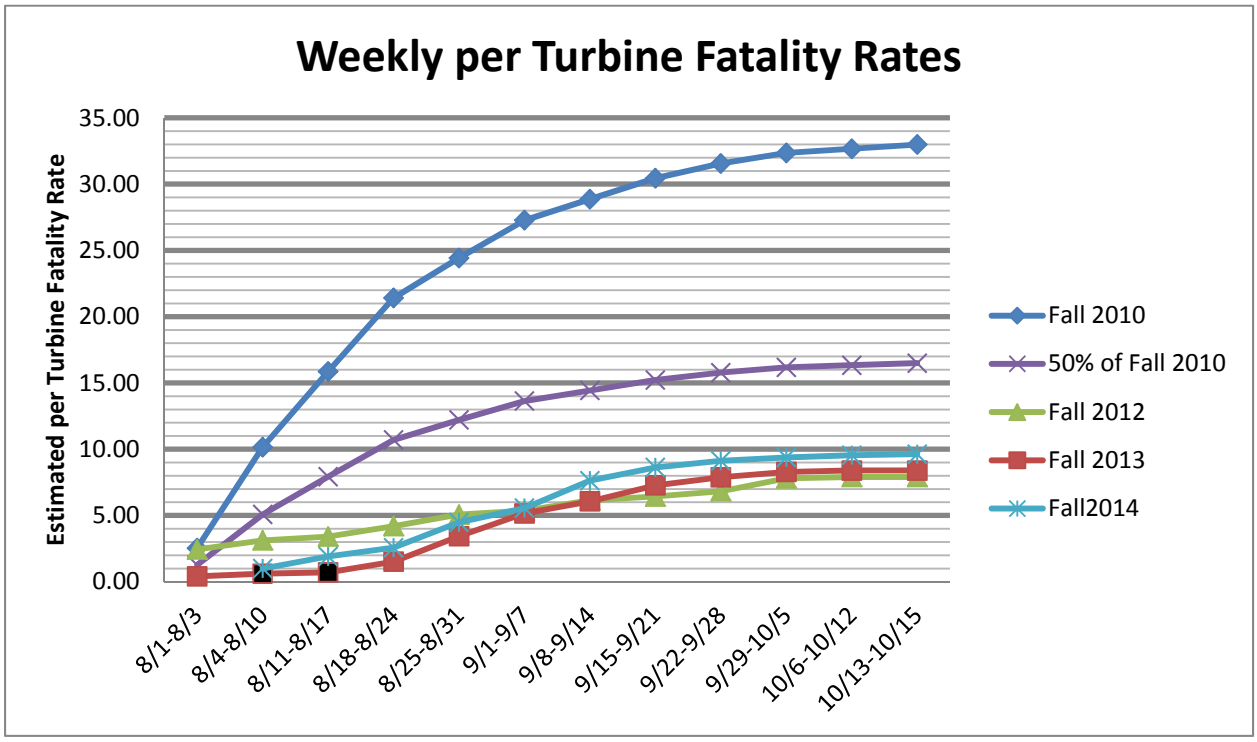

Figure 8. Weekly per turbine fatality rates (number of bat carcasses found per turbine) at the Fowler Ridge Wind Farm in 2010, 2012, 2013, 2014 and 50% of Fall 2010. This graph was used to determine if weekly fatality rates were approaching the 50% Adaptive Management Threshold. Fatality rates for 2014 shown in Figure 8 were based on 2013 bias trial results. The black squares during the weeks of August 4 and August 11 in 2013 represent the time period when much of the Fowler Ridge Wind Farm was not operating due to a scheduled shut down for maintenance.

DISCUSSION

The results of monitoring during 2014 provided evidence that operation strategies exceeded the objective of reducing bat casualty rates by 50% compared to casualty estimates of turbines in normal operation modes in 2010. The 77% - 84% reduction in point estimates of overall bat casualty rates observed in 2012, 2013, and 2014 compared to 2010 were greater than expected based on earlier curtailment studies at the FRWF (Good et al. 2011, 2012). The most likely explanation relates to differences between raising cut-in speeds versus blade feathering; turbine cut-in speeds were raised but blades were not feathered during the 2010 study (Good et al 2011). Feathering blades results in less rotation of blades at lower wind speeds and results in greater reductions in bat fatalities.

REFERENCES

Endangered Species Act (ESA). 1973. 16 United States Code (USC) § 1531-1544, Public Law (PL) 93-205, December 28, 1973, as amended, PL 100-478 [16 USC 1531 *et seq.*]; 50 Code of Federal Regulations (CFR) 402.

Good, R.E., W.P. Erickson, A. Merrill, S. Simon, K. Murray, K. Bay, and C. Fritchman. 2011. Bat Monitoring Studies at the Fowler Ridge Wind Energy Facility, Benton County, Indiana: April 13 - October 15, 2010. Prepared for Fowler Ridge Wind Farm. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming. January 28, 2011.

Good, R.E., A. Merrill, S. Simon, K. Murray, and K. Bay. 2012. Bat Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana: April 1 - October 31, 2011. Prepared for the Fowler Ridge Wind Farm. Prepared by Western EcoSystems Technology, Inc. (WEST), Bloomington, Indiana. January 31, 2012.

Good. R. E., M. Sonnenberg, and S. Simon, 2013. Bat Evaluation Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana. Final Report: August 1 – October 15, 2012. Prepared for Fowler Ridge Wind Farm, Fowler, Indiana. Prepared by Western EcoSystems Technology, Inc. Bloomington, Indiana.

Good. R. E., K. Adachi, C. Lebeau, S. Simon, and B. Hale. 2014. Bat Evaluation Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana. Final Report: August 1 – October 15, 2013. Prepared for Fowler Ridge Wind Farm, Fowler, Indiana. Prepared by Western EcoSystems Technology, Inc. Bloomington, Indiana.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Land Cover Database for the United States. Photogrammetric Engineering and Remote Sensing 70(7): 829-840.

Indiana Natural Heritage Data Center (INHDC). 2013. Benton County Endangered, Threatened and Rare Species List. INHDC, Division of Nature Preserves, Indiana Department of Natural Resources (IDNR). Updated June 1, 2010. Available online at: http://www.in.gov/dnr/naturepreserve/files/np_benton.pdf

Johnson, G.D., M. Ritzert, S. Nomani, and K. Bay. 2010a. Bird and Bat Fatality Studies, Fowler Ridge I Wind-Energy Facility Benton County, Indiana. Unpublished report prepared for British Petroleum Wind Energy North America Inc. (BPWENA) by Western EcoSystems Technology, Inc. (WEST).

Johnson, G.D., M. Ritzert, S. Nomani, and K. Bay. 2010b. Bird and Bat Fatality Studies, Fowler Ridge III Wind-Energy Facility, Benton County, Indiana. April 2 - June 10, 2009. Prepared for BP Wind Energy North America. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming.

US Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). 2006. Soil Survey Geographic (SSURGO) Database for Benton County, Indiana. USDA-NRCS. Fort Worth, Texas.

US Fish and Wildlife Service (USFWS). 2007. Indiana Bat (*Myotis sodalis*) Draft Recovery Plan: First Revision. US Department of Interior, Fish and Wildlife Service, Region 3. USFWS. Fort Snelling, Minnesota. 260 pp. http://ecos.fws.gov/docs/recovery_plan/070416.pdf

US Fish and Wildlife Service (USFWS). 2013. USFWS Website. Last updated December 2012. USFWS Endangered Species Program homepage: http://www.fws.gov/endangered/; Environmental Conservation Online System (ECOS): http://ecos.fws.gov/ecos/indexPublic.do; Threatened and Endangered Species System (TESS) listings by state: http://ecos.fws.gov/tess_public/pub/stateListingAndOccurrence.jsp; Individual species profiles and status information available from the ECOS webpage.

US Geological Survey (USGS). 2011-2013. The National Map/US Topo. Last updated January 22, 2013. Homepage available at: http://nationalmap.gov/ustopo/index.html

Whitaker, J.O. and R.E. Mumford, eds. 2009. Mammals of Indiana. Indiana University Press. 660 pp.

Appendix A. Estimated Time of Death Information Sheet

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Last Night

- Eyes will be round and fluid filled or slightly dehydrated
- No decomposition
- No infestations other than flies and eggs
- Body may be more flexible

2 – 3 Days

- Eyes will be sunken or missing
- May be infested with maggots, beetles, flies, and ants
- Flesh and internal organs will begin to be scavenged by insects

4 – 7 Days

- Eyes will be completely gone
- Most internal organs will be missing
- Bat may look like a hollow shell
- Fur may begin to fall off the skin and bat may look like it expanded in size
- Few maggots may be present but not prevalent

7 – 14 Days

- There is almost no meat left on body
- Skin has conformed to the skeletal system
- Body cavity should be devoid of insects

> 2 Weeks to > **1 Month**

- Wing membrane is either gone or deteriorating
- Exposed bones are bleached in appearance

Appendix B. Complete Casualty Listing for the 2014 Casualty Monitoring at the Fowler Ridge Wind Farm

Appendix B. Complete casualty listing for the 2014 casualty monitoring at the Fowler Ridge Wind Farm.

Date	Common Name	Location	Turbine Type	Outside of Plot
8/4/2014	eastern red bat	432	Vestas	No
8/4/2014	hoary bat	411	Vestas	No
8/4/2014	hoary bat	448	Vestas	No
8/4/2014	hoary bat	203	Vestas	No
8/5/2014	mourning dove	47	GE	No
8/7/2014	hoary bat	334	Clipper	No
8/7/2014	hoary bat	641	Clipper	Yes
8/7/2014	eastern red bat	624	Clipper	No
8/7/2014	hoary bat	622	Clipper	No
8/7/2014	eastern red bat	631	Clipper	No
8/7/2014	eastern red bat	611	Vestas	No
8/7/2014	hoary bat	388	Vestas	No
8/8/2014	unidentified icterid	39	GE	No
8/8/2014	mourning dove	38	GE	No
8/8/2014	unidentified sparrow	39	GE	No
8/8/2014	eastern red bat	42	GE	No
8/11/2014	hoary bat	408	Clipper	Yes
8/11/2014	hoary bat	203	Vestas	No
8/11/2014	eastern red bat	459	Clipper	No
8/11/2014	eastern red bat	605	Clipper	No
8/11/2014	hoary bat	423	Vestas	No
8/11/2014	eastern red bat	603	NA	No
8/11/2014	barn swallow	639	Vestas	No
8/11/2014	eastern red bat	286	Vestas	No
8/12/2014	eastern red bat	99	GE	No
8/12/2014	eastern red bat	52	GE	No
8/12/2014	hoary bat	113	GE	No
8/12/2014	purple martin	83	GE	No
8/14/2014	big brown bat	605	Clipper	No
8/15/2014	common grackle	11	GE	No
8/18/2014	eastern red bat	476	Vestas	No
8/18/2014	eastern red bat	224	Vestas	No
8/19/2014	eastern red bat	198	Vestas	No
8/21/2014	silver-haired bat	267	Vestas	No
8/21/2014	eastern red bat	324	Vestas	No
8/21/2014	eastern red bat	459	Vestas	No
8/22/2014	hoary bat	6	GE	No
8/22/2014	eastern red bat	101	GE	No
8/25/2014	eastern red bat	448	Vestas	No
8/25/2014	purple martin	390	Vestas	No
8/25/2014	hoary bat	641	Clipper	No
8/28/2014	eastern red bat	371	Vestas	No
8/28/2014	eastern red bat	396	Clipper	Yes
8/28/2014	silver-haired bat	371	Clipper	No
8/28/2014	silver-haired bat	458	Clipper	No
8/28/2014	silver-haired bat	442	Vestas	No
8/28/2014	eastern red bat	229	Vestas	No
8/28/2014	eastern red bat	608	Vestas	No
8/28/2014	silver-haired bat	458	Vestas	No
8/28/2014	hoary bat	620	Vestas	No
8/28/2014	silver-haired bat	611	Vestas	No

Appendix B. Complete casualty listing for the 2014 casualty monitoring at the Fowler Ridge Wind Farm.

Date	Common Name	Location	Turbine Type	Outside of Plot
8/28/2014	eastern red bat	478	NA	No
8/28/2014	hoary bat	624	Vestas	No
8/28/2014	eastern red bat	339	Vestas	No
8/28/2014	silver-haired bat	439	Vestas	Yes
8/28/2014	hoary bat	229	NA	No
8/28/2014	eastern red bat	608	Vestas	No
8/28/2014	eastern red bat	458	Vestas	No
8/28/2014	hoary bat	478	Clipper	No
8/29/2014	eastern red bat	82	GE	No
8/29/2014	hoary bat	125	GE	No
8/29/2014	Tennessee warbler	61	GE	Yes
8/29/2014	eastern red bat	101	GE	No
9/1/2014	eastern red bat	622	Vestas	No
9/1/2014	silver-haired bat	375	Vestas	No
9/1/2014	eastern red bat	309	Vestas	No
9/1/2014	hoary bat	355	Vestas	No
9/1/2014	eastern red bat	459	Vestas	No
9/1/2014	eastern red bat	401	Vestas	No
9/1/2014	eastern red bat	398	Clipper	No
9/2/2014	eastern red bat	254	Vestas	Yes
9/2/2014	eastern red bat	604	NA	Yes
9/2/2014	eastern red bat	195	NA	No
9/4/2014	hoary bat	371	Vestas	No
9/4/2014	hoary bat	635	Clipper	No
9/5/2014	eastern red bat	22	GE	No
9/8/2014	silver-haired bat	429	Vestas	No
9/8/2014	silver-haired bat	334	Vestas	No
9/8/2014	silver-haired bat	454	Vestas	No
9/8/2014	eastern red bat	429	Vestas	No
9/9/2014	eastern red bat	195	Vestas	No
9/9/2014	eastern red bat	11	GE	No
9/9/2014	eastern red bat	123	GE	No
9/9/2014	eastern red bat	109	GE	No
9/9/2014	eastern red bat	110	GE	No
9/11/2014	hoary bat	428	Clipper	Yes
9/11/2014	silver-haired bat	608	Clipper	No
9/11/2014	eastern red bat	339	Clipper	No
9/11/2014	silver-haired bat	623	Clipper	No
9/11/2014	silver-haired bat	369	Clipper	No
9/11/2014	silver-haired bat	348	NA	No
9/11/2014	silver-haired bat	241	Vestas	Yes
9/11/2014	silver-haired bat	627	Vestas	No
9/11/2014	silver-haired bat	639	Vestas	No
9/11/2014	silver-haired bat	369	Vestas	No
9/11/2014	silver-haired bat	627	NA	No
9/11/2014	silver-haired bat	639	Vestas	No
9/11/2014	eastern red bat	309	Vestas	No
9/11/2014	silver-haired bat	309	Clipper	Yes
9/12/2014	silver-haired bat	30	GE	No
9/12/2014	eastern red bat	110	GE	No
9/16/2014	silver-haired bat	324	Vestas	No

Appendix B. Complete casualty listing for the 2014 casualty monitoring at the Fowler Ridge Wind Farm.

Date	Common Name	Location	Turbine Type	Outside of Plot
9/16/2014	silver-haired bat	611	Vestas	No
9/16/2014	silver-haired bat	444	Vestas	No
9/16/2014	silver-haired bat	444	Vestas	No
9/16/2014	silver-haired bat	359	Vestas	No
9/16/2014	silver-haired bat	390	Vestas	No
9/16/2014	silver-haired bat	369	Clipper	No
9/16/2014	silver-haired bat	612	Clipper	No
9/17/2014	silver-haired bat	46	GE	Yes
9/17/2014	silver-haired bat	7	GE	No
9/18/2014	silver-haired bat	621	NA	Yes
9/19/2014	hoary bat	291	NA	Yes
9/22/2014	yellow-billed cuckoo	251	Vestas	No
9/25/2014	eastern red bat	355	Vestas	No
9/25/2014	tricolored bat	641	Vestas	No
9/25/2014	Tennessee warbler	622	Clipper	No
9/25/2014	silver-haired bat	459	Clipper	No
9/26/2014	eastern red bat	193	Vestas	No
9/26/2014	silver-haired bat	22	GE	No
9/26/2014	silver-haired bat	26	GE	No
9/29/2014	silver-haired bat	605	Vestas	No
9/29/2014	unidentified warbler	423	Clipper	No
9/30/2014	common grackle	11	GE	Yes
10/2/2014	mourning dove	608	Clipper	No
10/2/2014	eastern red bat	639	Clipper	No
10/3/2014	hoary bat	99	GE	No
10/6/2014	silver-haired bat	309	Vestas	No
10/7/2014	ruby-crowned kinglet	50	GE	No
10/10/2014	hoary bat	422	NA	Yes
10/13/2014	silver-haired bat	230	Vestas	No
10/13/2014	mourning dove	245	Vestas	No