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

August 3 – October 12, 2016

Prepared for:

Fowler Ridge Wind Farm

Prepared by:

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January 31, 2017

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REPORT REFERENCE

Good. R. E., A. Ciecka, G. Iskali, and K. Nasman. 2017. Bat Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana: August 3 – October 12, 2016. Prepared for Fowler Ridge Wind Farm, Fowler, Indiana. Prepared by Western EcoSystems Technology, Inc. Bloomington, Indiana.

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 consists of 420 wind turbines in four 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 U.S. Fish and Wildlife Service 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 August of 2014 (TE95012A-0). Monitoring the effectiveness of minimization measures is required by both the Habitat Conservation Plan and the Incidental Take Permit. Two years of Evaluation Phase monitoring, utilizing a larger sample of turbines to test effectiveness of applied minimization procedures, was completed for FRWF Phases I, II and III in 2014 and 2015. Because Indiana bat mortality was below adaptive management thresholds, Implementation Phase monitoring was completed for FRWF Phases I, II and III in 2016 and will continue unless adaptive management thresholds are exceeded in the future. Evaluation Phase monitoring, requiring a minimum of 33% of turbines to be searched, was completed at FRWF Phase IV in 2016 during its first year of operation.

The 2016 casualty study occurred during the fall (August 1 – October 15) migration period for Indiana bats. Casualty searches were completed once per week on roads and gravel pads of 140 turbines from August 3 – October 12, 2016. Personnel trained in proper search techniques conducted the carcass searches. Bias trials of searcher efficiency and carcass removal trials were conducted to adjust for removal bias and searcher efficiency.

A total of 129 bat carcasses were found in 2016 during carcasses searches and incidentally. Similar to previous years of monitoring, the most commonly found bat species were eastern red bats, silver-haired bats, and hoary bats. Three big brown bats and one evening bat (state endangered) were also found. No Indiana bat or any other *Myotis* spp. carcasses were found.

Bat casualty 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 casualty rates in 2016 were estimated to be 4.54 bat casualties/MW/study period (90% confidence interval 3.42 – 6.05), which was 72.3% lower than casualty estimates at turbines operating normally in 2010. The results of monitoring during 2016 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 (for minimization strategies) were not required in 2016 because bat casualty rates were well below adaptive management thresholds.

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INTRODUCTION

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 consists of 420 wind turbines in four 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 which an Indiana bat carcass (*Myotis sodalis*) 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 this research were used by the FRWF to design a strategy for reducing 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 (ITP) for Indiana bats in August of 2014 (TE95012A-0) based on the HCP. The ITP and HCP include requirements for monitoring the effectiveness of minimization measures. The first two years of evaluation phase monitoring were completed in 2014 (Good et al. 2015) and 2015 (Good et al. 2016) for Phases I, II and III. Because Indiana bat mortality was estimated to be below adaptive management thresholds outlined within the HCP, implementation phase monitoring was conducted in 2016 at Phases I, II and III. Evaluation phase monitoring was conducted at Phase IV in 2016.

STUDY AREA

The FRWF currently has a total energy capacity of 750 megawatts (MW). Phase I consists of 122 Vestas V82 1.65-MW turbines and 40 Clipper C96 2.5-MW turbines with a combined total of 301 MW of energy capacity. Phase II consists of 133 1.5-MW General Electric (GE) SLE turbines with a capacity of 199.5 MW. Phase III consists of 60 Vestas V82 1.65-MW turbines with a total of 99 MW of capacity. Phase IV consists of 65 Siemens SWT-2.3-108 2.3-MW turbines with a capacity of 150 MW. The four 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
Siemens SWT-2.3-108	2.3	80	108	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 was constructed in 2015 and became operational in December 2015.

The FRWF is located in western Indiana in Benton County. 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. Elevations in the project area range from approximately 700 to 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 [USDA] Natural Resource Conservation Service [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 (Figure 1). Within one half-mile (0.80 kilometers) of turbine locations, cultivated crops comprise about 92.6% of the land use for the study area (Table 2). After tilled agriculture, the next most common land uses within the FRWF are developed areas (e.g., houses and buildings), which compose 5.4% of the total, and pastures/hayfields, which compose 1.5% of the total area. Forested areas, wetland and grasslands are rare within the study area (0.4%, 0.01% and 0.04%, respectively) (Homer et al. 2015, US Geological Survey [USGS] National Land Cover Database [NLCD] 2011).

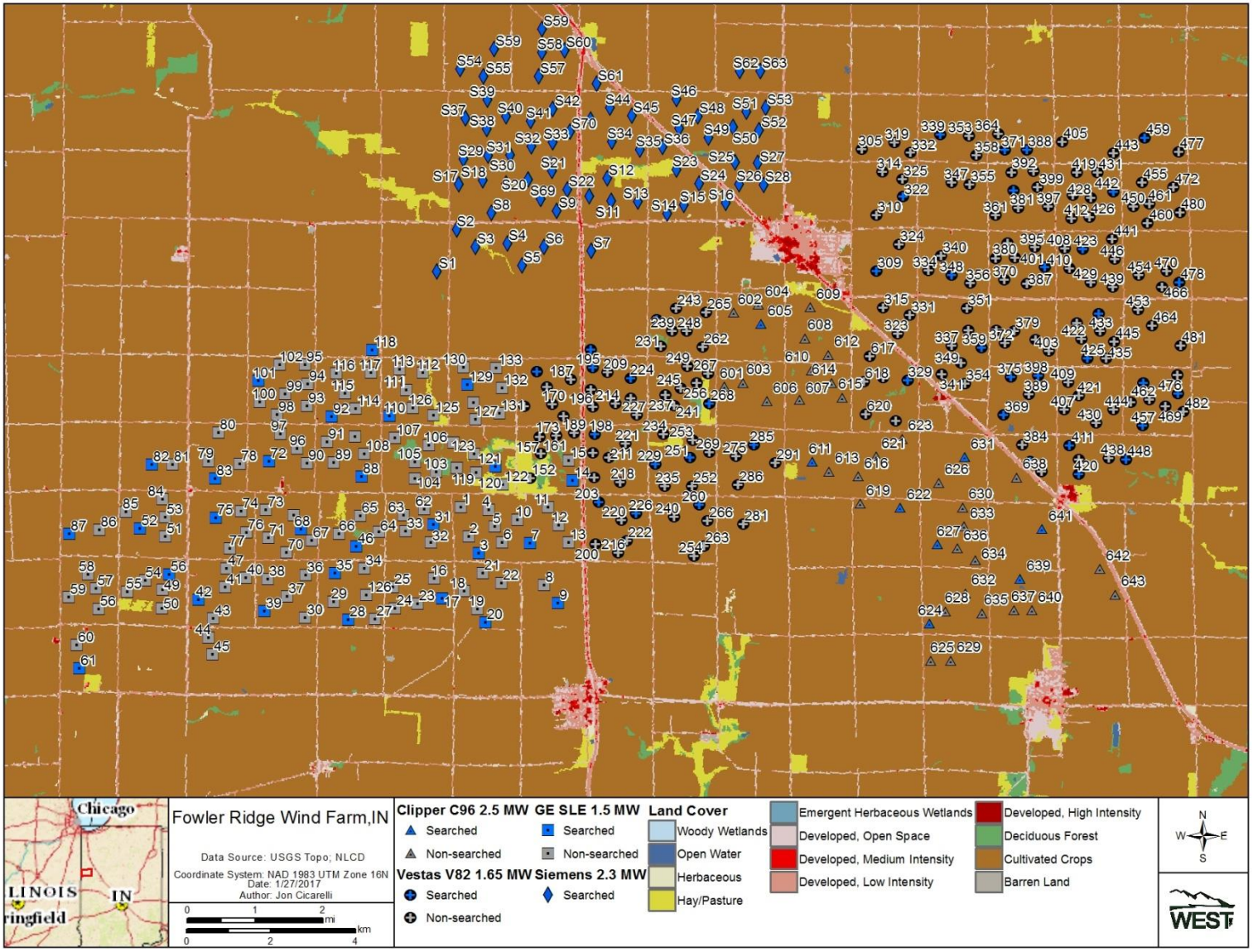

Figure 1. Land cover and locations of Phase I-IV turbines at the Fowler Ridge Wind Farm (NLCD 2011, Homer et al. 2015).

Table 2. Land cover within a half-mile of turbine locations within the Fowler Ridge Wind Farm (NLCD 2011, Homer et al. 2015).

Habitat Type	Acres	Percent Composition
Cultivated Crops	61,472.6	92.6%
Developed, Low Intensity	1,985.3	3.0%
Developed, Open Space	1,489.7	2.2%
Hay/Pasture	1,015.6	1.5%
Deciduous Forest	267.1	0.4%
Developed, Medium Intensity	91.4	0.1%
Open Water	34.4	0.1%
Herbaceous	27.3	<0.1%
Developed, High Intensity	26.1	<0.1%
Barren Land	8.4	<0.1%
Emergent Herbaceous Wetlands	4.0	<0.1%
Woody Wetlands	1.2	<0.1%
Total	**66,423.1**	**100.00%**

METHODS

Season

The 2016 casualty study was completed from August 3 – October 12. 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 were found at the FRWF.

Search Plot and Sample Size

The FRWF is comprised of 355 turbines in Phases I, II and III, and 65 turbines in Phase IV (Figure 1). A smaller subset of turbines was searched at Phases I, II and III in 2016 than in 2015 (75 compared to 118) per the implementation phase monitoring protocols described in the HCP. All 65 turbines were searched in 2016 for the first year of evaluation phase monitoring at Phase IV (Figure 1). Carcass searches were conducted along access roads and turbine pads within 80 m (262 ft) of the turbine.

Search Frequency

Turbines were searched weekly. The search interval was based on the mean carcass removal time of 13.89 days recorded during monitoring at FRWF in 2015 (Good et al. 2016).

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 80 m (262 ft) of a sampled turbine. 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 five m (16 ft) intervals, and searchers scanned the area on both side sides out to approximately 2.5 m (about eight ft) for carcasses 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 each morning and they were completed before sunset.

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.
- Dismembered – a carcass that is found in more than one piece and pieces are separated by more than 5 meters.
- Feather Spot (for bird carcasses only) – 10 or more body feathers and/or at least two primary feathers, which indicated predation or scavenging.

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

Carcasses found in non-search areas (e.g., near a turbine not included in the sample of search area or outside of the search boundary for a searched turbine) were coded as incidental discoveries, collected, and documented in a similar fashion as those found during standard searches. 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 casualties for detection bias. Bias trials were conducted throughout the entire study period. Fifty-six bats were dropped from zero to six days prior to searches for bias trials (Table 3). When possible, freshly killed bats conclusively identified as non-*Myotis* or non-*Nycticeius humeralis* were used for searcher efficiency and carcass removal trials. Seven freshly killed bats were placed for searcher efficiency trials and the rest of the bat carcasses were obtained from Indiana State University.

Bat carcasses were placed throughout the study session by a biologist not involved in the carcass search effort, and were randomly 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 and bearing from the turbine. Carcasses were identified as bias trial carcasses through the placement of small, indistinct black zip ties on the bats' wings. Carcasses were left in the field for up to 24 days, resulting in searchers having three 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.

Table 3. Searcher efficiency carcasses placed and used for the empirical pi method by time since death for post-construction casualty monitoring at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Number of Days Prior to Search	Number Placed	Used for Analysis
0	20	6
1	6	6
2	6	6
3	5	5
4	7	6
5	6	6
6	6	6
Total	56	41

Twenty bat carcasses were monitored to estimate removal rates. Carcasses were 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 day after a carcass was placed.

Statistical Analysis

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 SQL Server 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.

Bat Mortality Estimation

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

1) Observed number of bat carcasses found on search plots 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 search plot were included in the casualty analysis if the bat was estimated to have perished on or after the evening of July 31, 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 measuring searcher efficiency and carcass removal. 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 pi estimate of the probability of availability and detection. This method was used during previous study years at the FRWF.

A correction factor (r) of 6.56 was used to adjust for carcasses that likely occurred outside of searched roads and pads for Fowler I - III, 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 2011 and 2012 at Phases I, II and III of FRWF (Good et al. 2011, 2012).

A correction factor (r) of 26.38 was used to adjust for carcasses that likely occurred outside of searched roads and pads for Fowler IV, to determine total estimated bat mortality during the fall migration period. The area correction was modeled using data collected from 2012 through 2016 to account for unsearched area for road and pad searches for bats. Searched area was weighted as a function of distance from the turbine, because the areas near the turbine tend to have a higher density of bat carcasses than areas farther from the turbine (Huso and Dalthorp 2014). The result was an estimate of the proportion of bat casualties expected to land within searched and unsearched areas around turbines where only roads and pads were searched. A density distribution of carcasses was estimated by fitting truncated Weibull, truncated normal, truncated Gompertz, truncated Rayleigh, and truncated gamma density distributions to carcass distances (from turbines). The best-supported model was selected using an information theoretic approach known as AICc, or corrected Akaike Information Criteria (Burnham and Anderson 2002). Fits were obtained using a weighted maximum likelihood approach (Khokan et al. 2013), where the weight for each observed carcass distance was the inverse of the fraction of area searched at the distance where the carcass was found, multiplied by the inverse of the probability of detection ($\hat{\pi}$) for that carcass. This approach results in weighted maximum likelihood estimates of carcass detection probabilities that vary systematically with distance from turbines.

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

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

Carcass Removal Rates

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 2016 and the baseline year (2010) was calculated as the percent difference between estimates and compared to the anticipated 50% reduction in casualty rates due to applied minimization measures.

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.

Bat and Bird Carcasses

A total of 1,518 weekly surveys were conducted on roads and pads across 140 turbines from August 3 – October 12, 2016. Overall, 129 bat carcasses and 17 bird carcasses were found during the survey (Table 4; Appendix B).

Species Composition

The most commonly found bat species were eastern red bat (*Lasiurus borealis*; 73 carcasses, 56.6% of carcasses), followed by silver-haired bat (*Lasionycteris noctivagans;* 26 carcasses, 20.2%), and hoary bat (*Lasiurus cinereus*; 26 carcasses, 20.2%). Two other species were found: big brown bat (*Eptesicus fuscus;* 3 carcasses*,* 2.3%) and evening bat (*Nycticeius humeralis*; 1 carcass, 0.8%). The evening bat is listed as endangered by the Indiana Department of Natural Resources (Indiana Department of Natural Resources [IDNR] 2015). No Indiana bat or other *Myotis* spp. carcasses were found during the 2016 study (Table 4).

The seventeen bird carcasses found during the survey represent 11 individual known bird species and one unidentified warbler (Table 4). No bird species listed as threatened or endangered by the Indiana Department of Natural Resources (INHDC 2016), or federal endangered species (Endangered Species Act (ESA) 1973, USFWS 2016) were found. One Indiana species of special concern (IDNR 2015), the American golden plover (*Pluvialis dominica*) was found during surveys.

Table 4. Total number of bird and bat carcasses and the percent composition of carcasses found at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Species	Carcasses Found on Plots during Scheduled Searches and Estimated to Have Perished Prior to August 1		Incidental Carcasses at Search Plots Estimated to Have Perished Prior to August 1		Incidental Carcasses Found Outside of Search Plots or Estimated to Have Perished Prior to August 1		Total	
	Total	% Comp.	Total	% Comp.	Total	% Comp.	Total	% Comp.
Bats								
eastern red bat	44	53.7	2	40	27	64.3	73	56.6
hoary bat	15	18.3	1	20	10	23.8	26	20.2
silver-haired bat	22	26.8	2	40	2	4.8	26	20.2
big brown bat	1	1.2	0	0	2	4.8	3	2.3
evening bat	0	0.0	0	0	1	2.4	1	0.8
Total Bats	**82**	**100.0**	**5**	**100**	**42**	**100.0**	**129**	**100.0**
Birds								
mourning dove	2	18.2	0	0	2	40	4	23.5
chimney swift	1	9.1	0	0	1	20	2	11.8
American golden-plover	1	9.1	0	0	0	0	1	5.9
common grackle	1	9.1	0	0	0	0	1	5.9
European starling	1	9.1	0	0	0	0	1	5.9
indigo bunting	1	9.1	0	0	0	0	1	5.9
palm warbler	1	9.1	0	0	0	0	1	5.9
ruby-crowned kinglet	1	9.1	0	0	0	0	1	5.9
tree swallow	1	9.1	0	0	0	0	1	5.9
unidentified warbler	1	9.1	0	0	0	0	1	5.9
Tennessee warbler	0	0.0	1	100	0	0	1	5.9
killdeer	0	0.0	0	0	2	40	2	11.8
Total Birds	**11**	**100.00**	**1**	**100**	**5**	**100**	**17**	**100.0**

Estimated Time since Death

Most bat carcasses found on search plots and that were estimated to have been killed during the fall migration period were estimated to have been killed two to three days (42.5%) or four to seven days before the scheduled search (26.4%; Table 5). Less than 10% of bat carcasses had an estimated time of death beyond seven days (Table 5).

Table 5. Estimated time since death of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Estimated Time Since Death	Number of Carcasses	% Composition
Bats		
last night	21	24.1
2-3 days	37	42.5
4-7 days	23	26.4
7-14 days	1	1.1
>2 weeks	1	1.1
>month	0	0.0
unknown	4	4.6

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

Timing of Bat Carcasses

Bat carcasses occurred throughout the study period. The highest number of bats were found in late-August (08/22/2016 and 08/29/16). The number of bat carcasses found decreased in October and as the study ended (Figure 2).

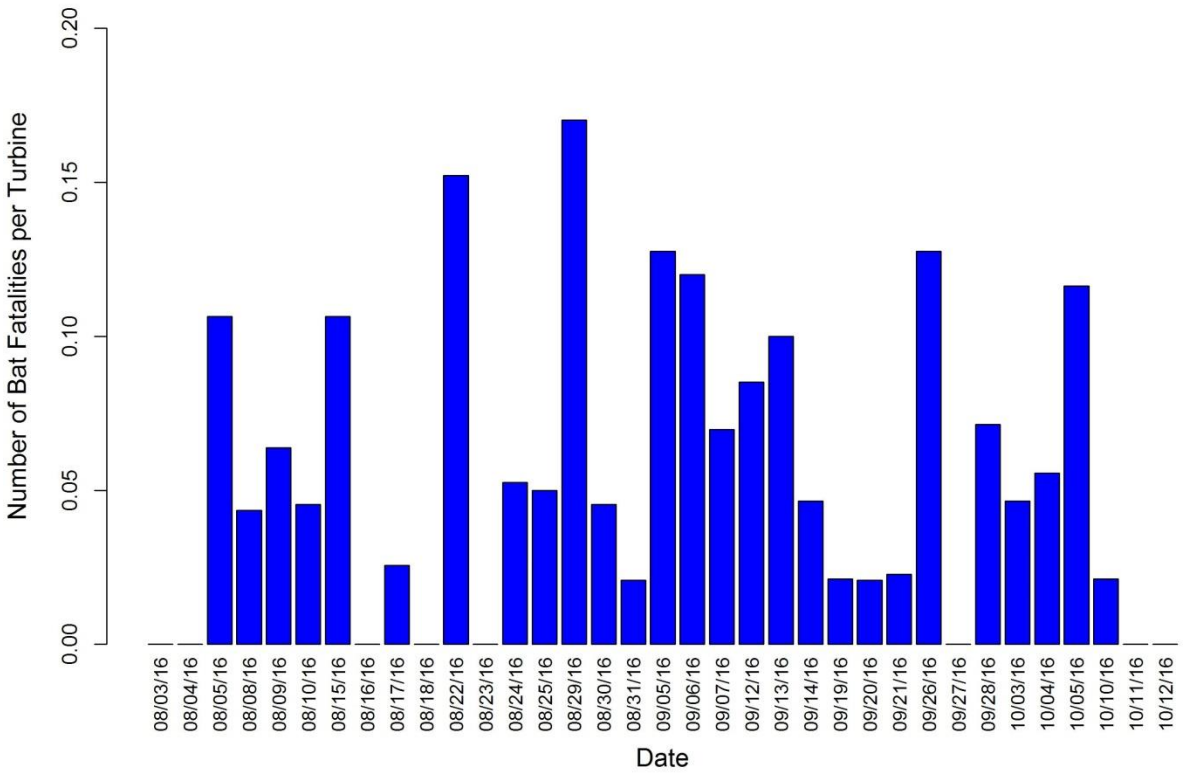

Figure 2. Timing of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Distribution of Bat Carcasses

A total of 93.1% of bat carcasses were found within 50 m (164.0 ft) of turbines, with the highest percentage (46%) of carcasses found between 0 – 10 m (0 – 32.8 ft), followed by 13.8% of bat carcasses each found between 20 – 30 m (65.6 – 98.4 ft) and 30 – 40 m (98.4 – 131.2 ft) from turbines (Table 6, Figure 3). This was a function of the amount of searchable area present within varying distances of turbines because roads and pads comprise a higher percentage of area in each distance band closer to turbines.

Table 6. Distribution of distances from turbines of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Distance to Turbine (m)	Number of Carcasses	% Composition
0 to 10	40	46.0
10 to 20	10	11.5
20 to 30	12	13.8
30 to 40	12	13.8
40 to 50	7	8.0
50 to 60	2	2.3
60 to 70	2	2.3
70 to 80	2	2.3
80 to 90	0	0.0

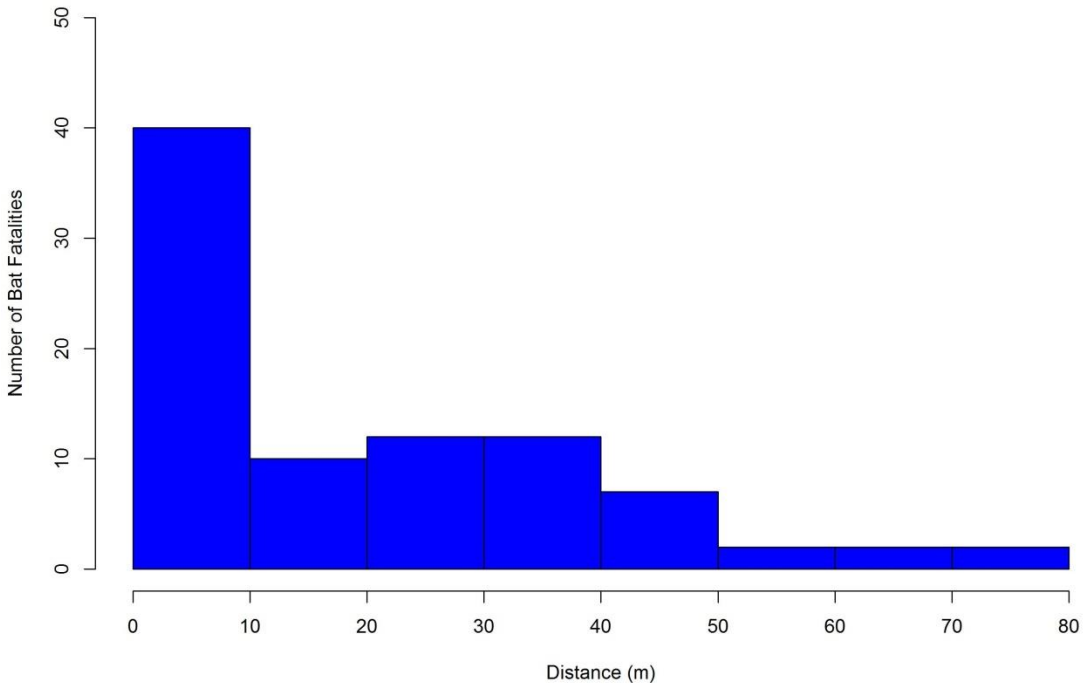

Figure 3. Distribution of distances from turbines of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Bat Carcasses by Turbine Location

Bat carcasses occurred more frequently in the central and eastern portions of the FRWF (Figure 4). The highest observed casualty rates occurred at the Clipper turbines with 14 carcasses on 8 searched turbines, for a rate of 1.75 observed bat carcasses per turbine, followed by Vestas with 33 carcasses found at 39 Vestas turbines (0.85 observed bat carcasses per turbine). Thirty bat carcasses were found at 65 Siemens turbines (0.46 observed bat carcasses per turbine) and 10 bat carcasses were found on 28 GE turbines (0.36 bat carcasses per turbine). However, the size of the roads and pads area under Phase IV (Siemens) turbines was smaller than Phases I-III (Clipper, Vestas and GE turbines).

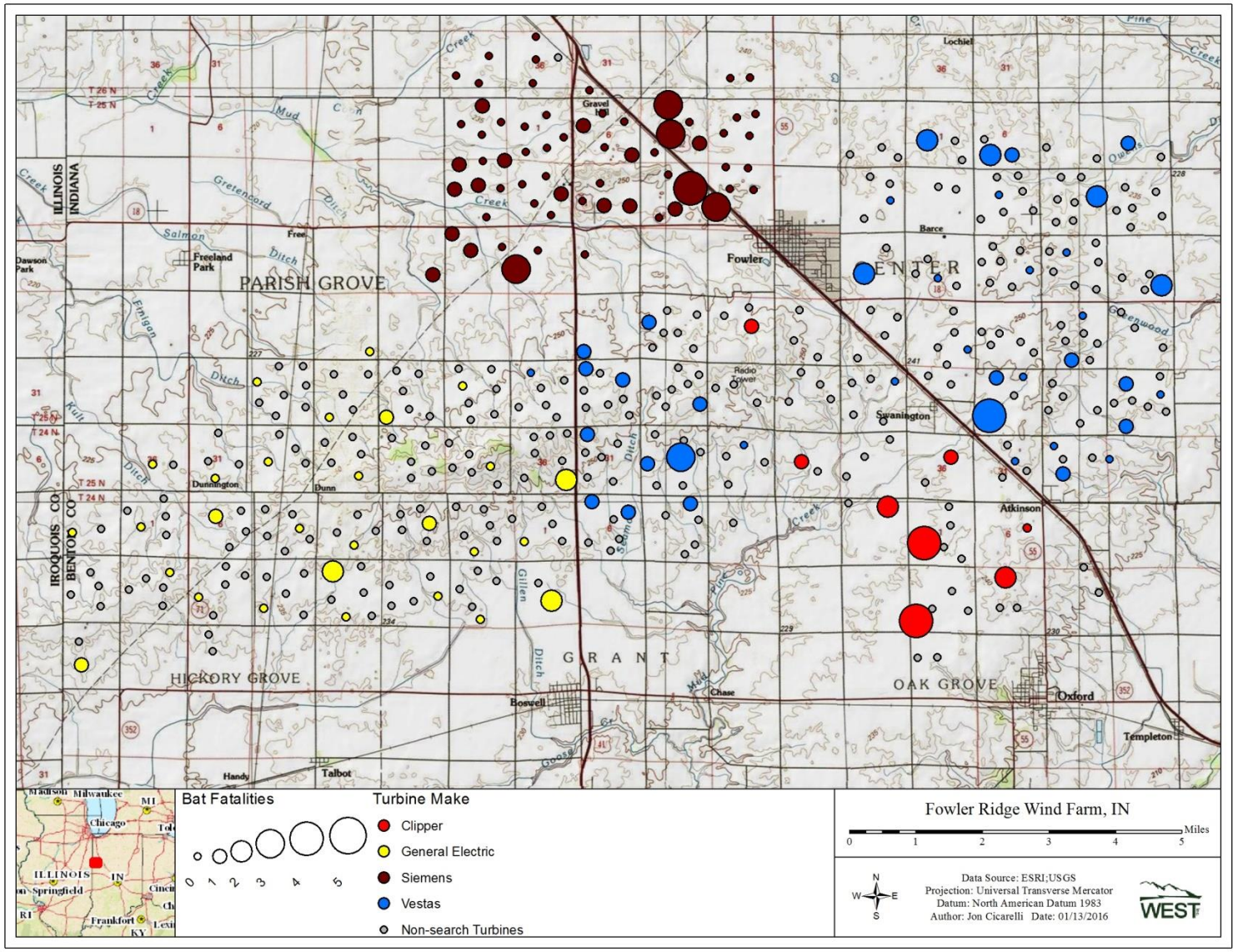

Figure 4. Number of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Bias Trials

Bias trials were conducted throughout the study period at seven placement intervals. Forty-one bats were placed from zero to six days prior to searches to estimate the overall probability that a bat carcass was available and detected. Twenty seven of the 41 trial carcasses were found at the next scheduled search (Table 7), with two additional bats found after multiple searches, resulting in an overall probability of a carcass being available and detected of 70.7% (Table 7). The probability that a carcass was available and detected in 2016 was slightly higher than most of the previous years where weekly searches were completed (i.e., 2015 [61.0%; Good et al. 2016], 2013 [55.5%; Good et al. 2014], 2012 [56.7%; Good et al. 2013] and 2010 [51%; Good et al. 2011]), but lower than 2014 (80.0%, Good et al. 2015).

Table 7. Searcher efficiency based on empirical pi methodology for post-construction casualty monitoring at the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Number of Days Prior to Search	Number Placed	Number Found on Next Search	Total Found	Percent Found
0	6	6	6	100.0
1	6	4	4	66.7
2	6	3	5	83.3
3	5	4	4	80.0
4	6	3	3	50.0
5	6	3	3	50.0
6	6	4	4	66.7
Total	**41**	**27**	**29**	**70.7**

A total of 20 bats were used to measure carcass removal rates. The average length of stay for bat carcasses in 2016 was 20.08 days. The carcass removal estimates for 2016 were slightly longer than rates observed in 2015 (13.89 days, Good et al. 2016), 2014 (19.36 days, Good et al. 2015) and 2011 (15.1 days; Good et al. 2012), and more than triple the estimate of 2013 (5.8 days; Good et al. 2014).

Adjusted Casualty Estimates

Forty-two bat carcasses were not included in analyses because carcasses were found outside of search plots or were estimated to have perished before July 31 (Appendix B). Eighty seven bat carcasses were included in the casualty estimate, resulting in an observed casualty rate of 0.62 bats per turbine. The observed casualty rate was then divided by the empirical probability of availability and detection (0.71). The value was multiplied by the road and pad correction factor (6.56 for Fowler I-III, 26.38 for Fowler IV) to obtain the per turbine adjusted casualty estimate for each type of turbine. The adjusted casualty estimate for the facility was weighted by the number of each turbine type present in the FRWF. The adjusted casualty estimate for the 2016 study was 8.66 bat casualties/turbine/study period (Table 8), or 4.54 bat casualties/MW/study period. The adjusted bat casualty rate was highest at Clipper turbines and Siemen turbines (Table 9).

Table 8. Number of bat casualties per turbine per study period for the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

Estimator		Estimate	Standard Deviation	90% Confidence Interval	
				Lower Limit	Upper Limit
Area Adjustment	Fowler I - III	6.56	-	-	-
	Fowler IV	26.38	-	-	-
Casualties per turbine		0.62	0.09	0.49	0.77
Empirical pi		0.71	0.07	0.60	0.81
Adjusted number of casualties per turbine		8.66	1.54	6.64	11.47

Table 9. Adjusted bat casualty estimates (empirical pi) for different turbine types within the Fowler Ridge Wind Farm from August 3 to October 12, 2016.

	Adjusted Overall Casualty Estimate and 90% Confidence Intervals	
	Mean	CI
	# casualties/turbine/year	
GE	3.31	1.36 – 5.68
Clipper	16.23	5.94 – 28.92
Vestas	7.85	4.94 – 11.51
Siemens	17.21	10.89 – 25.58
All Turbines	8.66	6.64 – 11.47
	# casualties/MW/year	
GE	2.21	0.90 - 3.79
Clipper	6.49	2.28 – 11.57
Vestas	4.76	3.00 - 6.98
Siemens	7.48	4.73 – 11.12
All Turbines	4.54	3.42 – 6.05

Comparison to 2010 Casualty Estimates

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). Estimates of 2016 casualty estimates from turbines feathered until wind speeds reached 5.0 m/s were 72.3% lower than the road and pad casualty estimates at turbines operating normally in 2010, with an estimated 8.66 bat casualties/turbine/study period (90% CI 6.64 – 11.47).

Uncertainty surrounding bat casualty rates was estimated using 90% confidence intervals. Casualty rates from 2016 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, 2014, 2015 and 2016 (Figure 5).

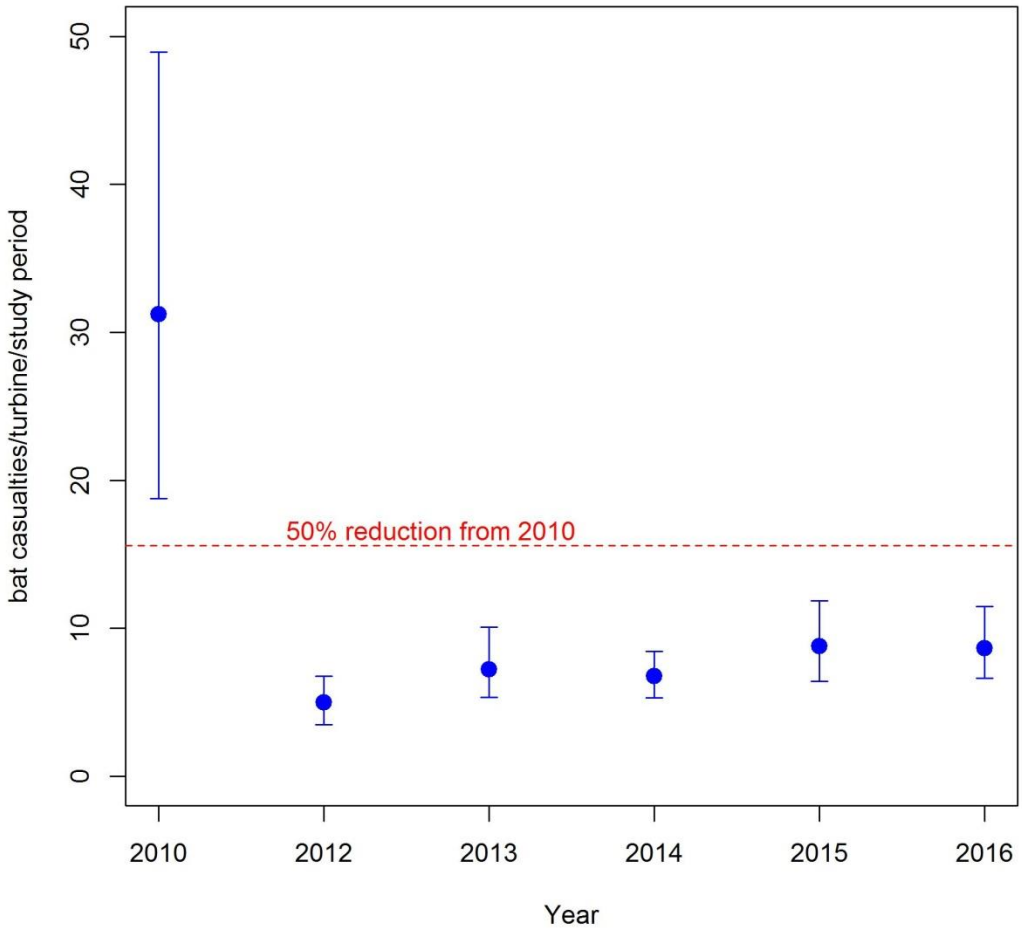

Figure 5. A comparison of estimated bat casualty rates and 90% confidence intervals for Fowler Ridge Wind Farm. The 2010 estimate represents turbines operating at manufacturer cut-in speeds. The 2012, 2013, 2014, 2015 and 2016 estimates represent data collected at turbines that were feathered below 5.0 m/s. The red dotted line represents a 50% reduction in bat casualty rates compared to the 2010 estimate.

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 were 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: 11.2 Indiana bats per year for the entire facility.

The Fowler HCP prescribes a sampling approach utilizing roads and pads to calculate casualty 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 from the previous year's monitoring results were applied (Table 10). The within season adaptive management threshold for 2016 was 145.9 bat carcasses. A total of 87 bat carcasses were found on search plots that were estimated to have been killed on or after the evening of July 31 during the study.

Figure 6 illustrates the within-season tracking tool that was used to determine if mortality was approaching within-season adaptive management thresholds. The weekly 2016 estimated bat casualty rate shown in Figure 6 was an estimate calculated using the 2015 bias trial data. The final 2016 bat casualty estimate was based on 2016 bias trial results. Adaptive Management thresholds were not exceeded at any time during the study, and no changes to minimization efforts were required during 2016.

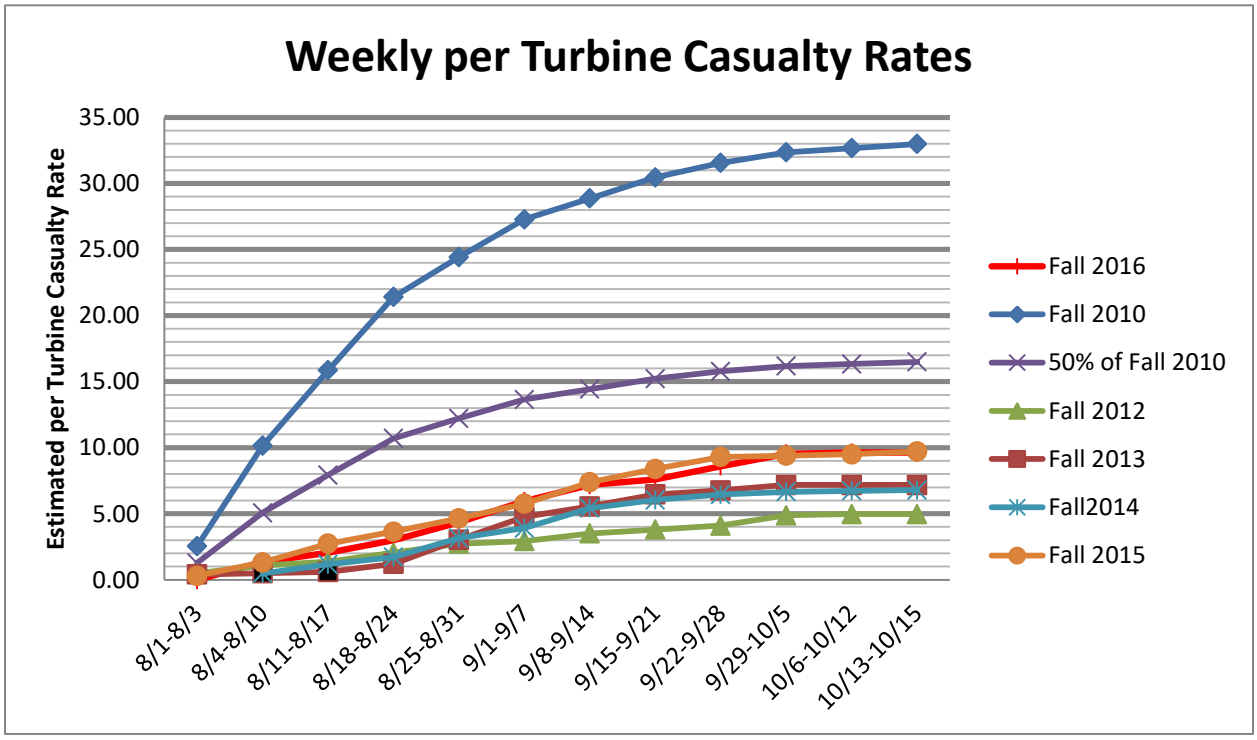

Figure 6. Weekly per turbine casualty rates (number of bat carcasses found per turbine) at the Fowler Ridge Wind Farm in 2010, 2012, 2013, 2014, 2015, 2016 and 50% of fall 2010. This graph was used to determine if weekly casualty rates were approaching the 50% Adaptive Management Threshold. Fatality rates for 2016 shown above were based on 2015 bias trial results. The black squares during the weeks of August 4 and August 11 in 2013 represent the time when much of the Fowler Ridge Wind Farm was not operating due to a scheduled shutdown for maintenance.

Table 10. Variables used to calculate the within-season adaptive management threshold for 420 operational turbines in 2016 (Phases I, II, III, IV).

Parameter	Fowler I-III	Fowler IV	Description of Where Data Came From
Adaptive Management Threshold for Indiana Bats	11.2		Upper quartile (i.e., 75th percentile) of estimated fall bat mortality in 2010 and 2011 at control turbines with minimization measures in place
Percent of All Casualties that are Indiana Bats	0.16		Percentage based on total number of Indiana bats found during searches over total bats found, as described within the HCP
Estimated Upper Quartile of Total Casualties During the Period for which Adaptive Management Thresholds are Based	7,016		Calculated – 11.22 / 0.0016
Number of Turbines	355	65	Fowler Phases I, II, III and IV
Estimated Upper Quartile of All Bat Casualty Rate per Turbine During the period for which Adaptive Management Thresholds are Based	16.7		Estimated by dividing the bat mortality count (7,016) by the number of operational turbines (420).
Empirical PI Estimate	0.61		Estimated probability of carcass being available and detected based on Fowler 2015 empirical bias trials from weekly road/pad searches; will be adjusted annually for subsequent years
Road & Pad Correction Factor	6.56	22.56	Phases I, II and III based on number of bats found on road and pads of cleared plots in relation to the total number of bats found at cleared plots in 2010 and 2011. Phase IV based on road and pad area searched measured at Phase IV and modeled carcass density distribution based on carcass distance data collected at Fowler from 2012-2015 on roads and pads. The road and pad correction factor used to estimate within-season thresholds is different than the factor used to calculate end of season casualty estimates.

Table 10. Variables used to calculate the within-season adaptive management threshold for 420 operational turbines in 2016 (Phases I, II, III, IV).

Parameter	Fowler I-III	Fowler IV	Description of Where Data Came From
			The end of season correction factor includes carcass distribution information collected during 2016; the within season factor did not include 2016 data.
Predicted Upper Quartile of Number of Bats Found per Searched Turbine during the Period for which Adaptive Management Thresholds are Based	1.55	0.45	Predicted based on estimated casualty rate per turbine (16.7), multiplied by empirical PI (0.61), divided by road/pad correction factor (6.56 or 22.56)
Total Bats Found in One Fall Season Based on Turbines Searched	116.5	29.4	Predicted based on estimated number of bats found per turbine (1.55 or 0.45) multiplied by the number of turbines searched (75 or 65). Calculated value represents Adaptive Management Threshold for 2016
Total Bats Found Threshold	**145.9**		Sum of expected bat mortality from Phases I, II, III and IV

End of Season Indiana Bat Take Estimate

The estimated number of Indiana bat casualties that occurred during 2016 was calculated based on the overall estimated bat casualty rate during 2016, and the relative percent that Indiana bat carcasses comprised of all bat carcasses found during fall in 2009, 2010, and 2011 (0.16%). A total of 5.8 (90% CI 4.5 – 7.7) Indiana bat casualties were estimated to have occurred in 2016, which is lower than the number Indiana bats that were predicted to occur as casualties within the HCP after minimization. The estimated number of Indiana bat casualties fall below the 90% confidence intervals of Indiana bat casualties predicted within the HCP.

The end of year adaptive management threshold is equal to the upper bound of the 90% confidence interval for 2016 (Table 11). Per the terms of the HCP, no changes to minimization efforts are required for 2017.

Table 11. The estimated number of Indiana bat casualties compared to the number of predicted Indiana bat casualties at the Fowler Ridge Wind Farm while operating under incidental take permit TE95012A-0.

Year	Number of Operating Turbines	Estimated Number of Indiana Bat Casualties	Number of Indiana Bat Casualties Predicted to Occur within the HCP after Minimization		
			Lower 90% CI	Mean	Upper 90% CI
2014	355	4.1	7.0	8.6	10.6
2015	355	5.2	7.0	8.6	10.6
2016	420	5.8	8.8	10.9	13.4

DISCUSSION

The results of monitoring during 2016 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 71% – 84% reduction in estimates of overall bat casualty rates observed in 2012 through 2016 compared to 2010 were greater than expected, based on earlier curtailment studies at the FRWF (Good et al. 2011, 2012, 2013, 2014, 2015, 2016). 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 casualties.

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Appendix A. Estimated Time of Death Information Sheet

Estimated Time of Death Information Sheet

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. Bat and Bird Casualties Found at at the Fowler Ridge Wind Farm between August 1 – 15, 2016

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between August 1 – October 15, 2016

Date	Common Name	Location	Turbine Type*	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?
7/31/2016	eastern red bat	435	Vestas	yes	yes
8/3/2016	big brown bat	S15	Siemens	no	yes
8/3/2016	eastern red Bat	S15	Siemens	no	yes
8/3/2016	eastern red Bat	S53	Siemens	yes	yes
8/3/2016	mourning dove	S13	Siemens	no	yes
8/4/2016	eastern red bat	129	GE	no	yes
8/4/2016	killdeer	129	GE	no	yes
8/4/2016	mourning dove	39	GE	no	yes
8/5/2016	big brown bat	193	Vestas	no	yes
8/5/2016	eastern red bat	224	Vestas	no	no
8/5/2016	eastern red bat	329	Vestas	no	yes
8/5/2016	eastern red bat	369	Vestas	no	yes
8/5/2016	eastern red bat	378	Vestas	no	yes
8/5/2016	eastern red bat	417	Vestas	yes	no
8/5/2016	eastern red bat	442	Vestas	no	no
8/5/2016	eastern red bat	611	Clipper	no	no
8/5/2016	eastern red bat	625	Clipper	yes	no
8/5/2016	hoary bat	339	Vestas	no	no
8/5/2016	hoary bat	388	Vestas	no	yes
8/5/2016	hoary bat	459	Vestas	no	no
8/5/2016	hoary bat	476	Vestas	no	yes
8/8/2016	eastern red bat	457	Vestas	no	yes
8/8/2016	eastern red bat	624	Clipper	no	no
8/8/2016	hoary bat	251	Vestas	no	no
8/8/2016	hoary bat	425	Vestas	no	yes
8/9/2016	eastern red bat	61	GE	no	no
8/9/2016	eastern red bat	643	Clipper	yes	yes
8/9/2016	eastern red bat	643	Clipper	yes	no
8/9/2016	eastern red bat	643	Clipper	yes	no
8/9/2016	eastern red bat	81	GE	yes	no
8/9/2016	eastern red bat	9	GE	no	no
8/9/2016	eastern red bat	S22	Siemens	no	no
8/9/2016	eastern red bat	S33	Siemens	yes	no
8/10/2016	eastern red bat	S47	Siemens	no	no
8/10/2016	hoary bat	S36	Siemens	yes	no
8/10/2016	hoary bat	S57	Siemens	no	yes
8/10/2016	hoary bat	S60	Siemens	no	no
8/10/2016	killdeer	S63	Siemens	yes	no
8/15/2016	eastern red bat	309	Vestas	no	no
8/15/2016	eastern red bat	369	Vestas	no	no
8/15/2016	eastern red bat	375	Vestas	no	no
8/15/2016	eastern red bat	425	Vestas	no	no
8/15/2016	eastern red bat	627	Clipper	no	no
8/17/2016	eastern red bat	S11	Siemens	no	no

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between August 1 – October 15, 2016

Date	Common Name	Location	Turbine Type*	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?
8/17/2016	unidentified warbler	S50	Siemens	no	no
8/18/2016	eastern red bat	601	Clipper	yes	no
8/22/2016	eastern red bat	268	Vestas	no	no
8/22/2016	eastern red bat	364	Vestas	yes	no
8/22/2016	eastern red bat	420	Vestas	no	no
8/22/2016	eastern red bat	457	Vestas	no	no
8/22/2016	eastern red bat	624	Clipper	no	no
8/22/2016	eastern red bat	624	Clipper	no	no
8/22/2016	eastern red bat	627	Clipper	no	no
8/22/2016	hoary bat	442	Vestas	no	no
8/23/2016	chimney swift	S1	Siemens	no	no
8/24/2016	eastern red bat	S13	Siemens	no	no
8/25/2016	eastern red bat	240	Vestas	yes	no
8/25/2016	eastern red bat	640	Clipper	yes	no
8/25/2016	eastern red bat	640	Clipper	yes	no
8/25/2016	eastern red bat	S47	Siemens	no	no
8/26/2016	hoary bat	638	Clipper	yes	no
8/29/2016	eastern red bat	260	Vestas	no	no
8/29/2016	eastern red bat	339	Vestas	no	no
8/29/2016	eastern red bat	388	Vestas	no	no
8/29/2016	eastern red bat	631	Clipper	no	no
8/29/2016	eastern red bat	637	Clipper	yes	no
8/29/2016	hoary bat	195	Vestas	no	no
8/29/2016	hoary bat	198	Vestas	no	no
8/29/2016	hoary bat	605	Clipper	no	no
8/29/2016	hoary bat	627	Clipper	no	no
8/29/2016	hoary bat	633	Clipper	yes	no
8/30/2016	eastern red bat	35	GE	no	no
8/30/2016	eastern red bat	S29	Siemens	no	no
8/30/2016	indigo bunting	75	GE	no	no
8/31/2016	eastern red bat	71	GE	yes	no
8/31/2016	eastern red bat	S39	Siemens	no	no
9/1/2016	eastern red bat	S60	Siemens	no	no
9/1/2016	hoary bat	107	GE	yes	no
9/5/2016	eastern red bat	371	Vestas	no	no
9/5/2016	eastern red bat	478	Vestas	no	no
9/5/2016	hoary bat	226	Vestas	no	no
9/5/2016	hoary bat	251	Vestas	no	no
9/5/2016	silver-haired bat	369	Vestas	no	no
9/5/2016	silver-haired bat	458	Vestas	no	no
9/6/2016	common grackle	20	GE	no	no
9/6/2016	eastern red bat	S17	Siemens	no	no
9/6/2016	eastern red bat	S31	Siemens	no	no

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between August 1 – October 15, 2016

Date	Common Name	Location	Turbine Type*	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?
9/6/2016	hoary bat	14	GE	no	no
9/6/2016	hoary bat	S18	Siemens	no	no
9/6/2016	hoary bat	S5	Siemens	no	no
9/6/2016	silver-haired bat	75	GE	no	no
9/7/2016	eastern red bat	S40	Siemens	yes	no
9/7/2016	eastern red bat	S44	Siemens	yes	no
9/7/2016	European starling	S25	Siemens	no	no
9/7/2016	silver-haired bat	S24	Siemens	no	no
9/7/2016	silver-haired bat	S35	Siemens	no	no
9/12/2016	hoary bat	472	Vestas	yes	no
9/12/2016	hoary bat	472	Vestas	yes	no
9/12/2016	silver-haired bat	309	Vestas	no	no
9/12/2016	silver-haired bat	369	Vestas	no	no
9/12/2016	silver-haired bat	369	Vestas	no	no
9/12/2016	silver-haired bat	371	Vestas	no	no
9/12/2016	silver-haired bat	S3	Siemens	no	no
9/13/2016	silver-haired bat	110	GE	no	no
9/13/2016	silver-haired bat	35	GE	no	no
9/13/2016	silver-haired bat	9	GE	no	no
9/14/2016	big brown bat	S43	Siemens	no	no
9/13/2016	eastern red bat	14	GE	no	no
9/14/2016	hoary bat	S46	Siemens	no	no
9/14/2016	tree swallow	S40	Siemens	no	no
9/15/2016	evening bat	629	Clipper	yes	yes
9/15/2016	silver-haired bat	629	Clipper	yes	no
9/19/2016	eastern red bat	193	Vestas	no	no
9/20/2016	silver-haired bat	S2	Siemens	no	no
9/21/2016	chimney swift	S34	Siemens	yes	no
9/21/2016	eastern red bat	S46	Siemens	no	no
9/21/2016	mourning dove	S42	Siemens	no	no
9/26/2016	eastern red bat	622	Clipper	no	no
9/26/2016	hoary bat	639	Clipper	no	no
9/26/2016	silver-haired bat	203	Vestas	no	no
9/26/2016	silver-haired bat	478	Vestas	no	no
9/26/2016	silver-haired bat	622	Clipper	no	no
9/26/2016	silver-haired bat	639	Clipper	no	no
9/27/2016	Tennessee warbler	S17	Siemens	no	no
9/28/2016	eastern red bat	S24	Siemens	no	no
9/28/2016	eastern red bat	S49	Siemens	no	no
9/28/2016	silver-haired bat	S24	Siemens	no	no
10/3/2016	eastern red bat	251	Vestas	no	no
10/3/2016	silver-haired bat	624	Clipper	no	no
10/4/2016	eastern red bat	31	GE	no	no

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between August 1 – October 15, 2016

Date	Common Name	Location	Turbine Type*	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?
10/4/2016	mourning dove	88	GE	no	no
10/4/2016	silver-haired bat	S1	Siemens	no	no
10/4/2016	silver-haired bat	S5	Siemens	no	no
10/5/2016	eastern red bat	S16	Siemens	no	no
10/5/2016	eastern red bat	S16	Siemens	no	no
10/5/2016	eastern red bat	S24	Siemens	no	no
10/5/2016	eastern red bat	S60	Siemens	no	no
10/5/2016	palm warbler	S25	Siemens	no	no
10/5/2016	ruby-crowned kinglet	S44	Siemens	no	no
10/5/2016	silver-haired bat	640	Clipper	yes	no
10/5/2016	silver-haired bat	S15	Siemens	no	no
10/6/2016	eastern red bat	15	GE	yes	no
10/10/2016	silver-haired bat	229	Vestas	no	no
10/11/2016	American golden-plover	52	GE	no	no
10/11/2016	eastern red bat	39	GE	yes	no
10/13/2016	eastern red bat	419	Vestas	yes	no