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

August 1 – October 15, 2017

Prepared for:

Fowler Ridge Wind Farm

Prepared by:

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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 IV Wind Farm 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 which an Indiana bat carcass was found. The FRWF worked with the US 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 more intensive 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, less intensive implementation phase monitoring was applied for FRWF Phases I, II and III in 2016 and 2017, and will continue unless adaptive management thresholds are exceeded in the future. The second year of evaluation phase monitoring, requiring a minimum of 33% of turbines to be searched, was completed at FRWF Phase IV in 2017.

The 2017 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 1 – October 11, 2017. Personnel trained in proper search techniques conducted the carcass searches. Searcher efficiency and carcass persistence trials were conducted to adjust for removal bias and searcher efficiency.

A total of 130 bat carcasses were found in 2017 during carcass 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. Eight big brown bats, one Seminole bat and one evening bat (state-listed as endangered) were also found. No Indiana bat, northern long-eared bat or any other *Myotis* spp. carcasses were found.

Bat casualty rates were calculated based on the 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 2017 were estimated to be 5.24 bat casualties/MW/study period (90% confidence interval: 4.09 – 6.90), which was 66.3% lower than casualty estimates at turbines operating normally in 2010. The results of monitoring during 2017 provide evidence that operational strategies exceeded the objective of reducing bat casualty rates by 50%, compared to casualty estimates from turbines operating normally in 2010. Within-season adjustments of minimization strategies were not required in 2017 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 IV Wind Farm 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 turbine blades when winds were at 5.0 meters per second (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 and 2017 at Phases I, II and III. The second year of evaluation phase monitoring was conducted at Phase IV in 2017.

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 2.50-MW turbines with a combined total of 301 MW of energy capacity. Phase II consists of 133 1.50-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 2.30-MW turbines with a capacity of 150 MW. Turbine characteristics are listed in 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	1.50	80	77	3.5
Vestas V82	1.65	80	82	3.5
Siemens SWT-2.3-108	2.30	80	108	3.5
Clipper C96	2.50	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 dominated by cultivated crops, comprised primarily of corn (*Zea mays*) and soybeans (*Glycine max*) (Figure 1). Within 0.80 kilometers (approximately one half-mile) of turbine locations, cultivated crops compose 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, wetlands 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).

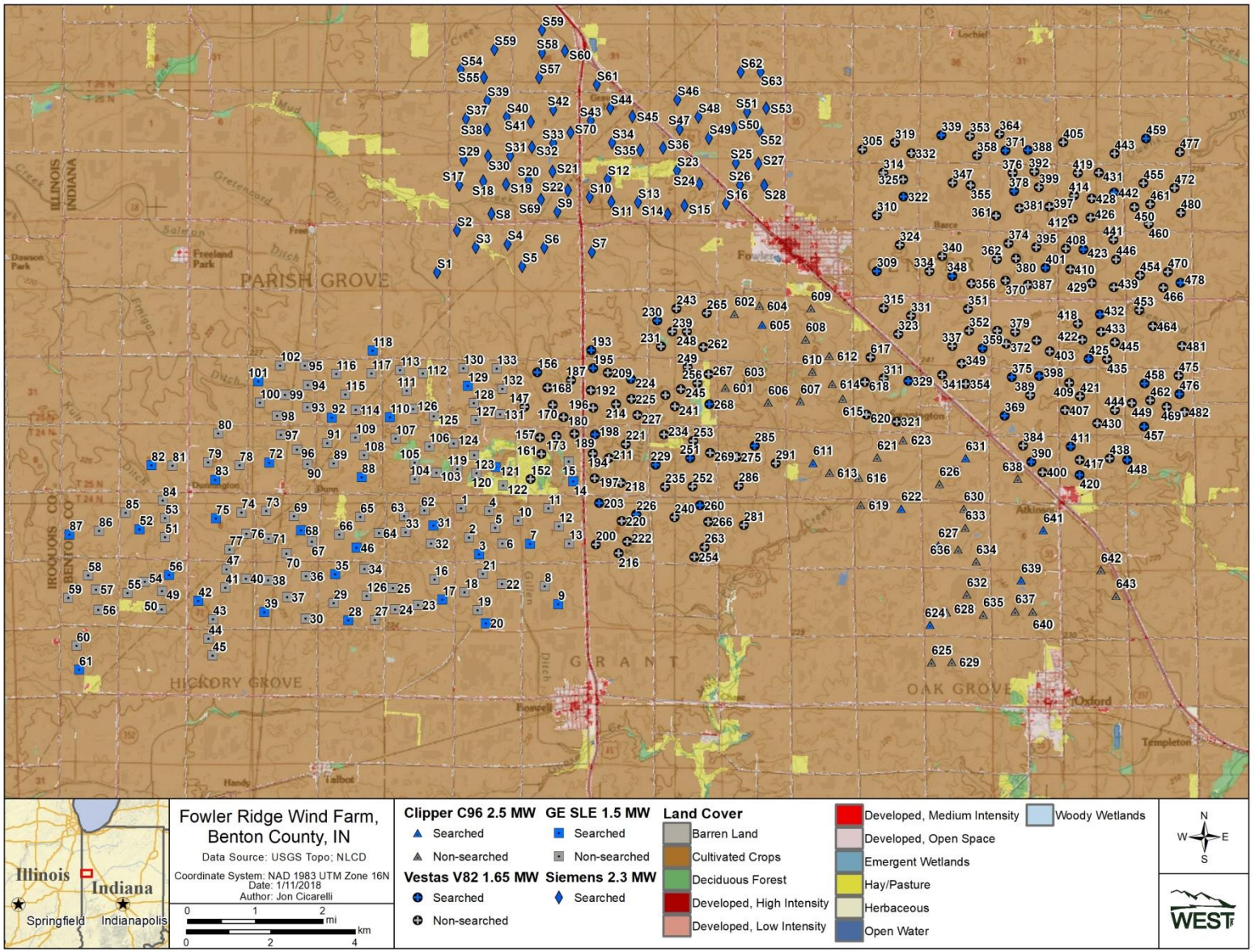

Figure 1. Land cover and locations of Phase I-IV turbines at the Fowler Ridge Wind Farm.

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%**

METHODS

Season

The 2017 casualty study was completed from August 1 – October 15. 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.

Sample Size

A total of 75 turbines were searched at Phases I, II and III per the implementation phase monitoring protocols described in the HCP. All 65 turbines were searched at Phase IV, which exceeded the HCP recommendations for evaluation phase monitoring (Figure 1).

Search Plot and Frequency

Carcass searches were conducted along access roads and on turbine pads within 80 m (262 ft) of the selected turbines (Figure 1). Turbines were searched weekly. The search interval was based on the mean carcass persistence time of 20.08 days recorded during monitoring at FRWF in 2016 (Good et al. 2017).

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, and 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 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 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), 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 five 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. Data recorded for each carcass included: species, sex and age when identifiable, 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 estimated and recorded. Criteria used to determine time since death are listed in Appendix A.

Carcasses found in non-search areas (e.g., near a turbine not selected for standardized carcass searches 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 were recorded and treated as a casualty for the purpose of the analyses.

Field Bias Trials

Searcher efficiency and removal of carcasses by scavengers were quantified to adjust the estimate of total bat casualties for detection bias. When possible, freshly killed bats conclusively identified as non-*Myotis* or non-evening bat (*Nycticeius humeralis*) were used for searcher efficiency and carcass persistence trials. Twenty freshly killed bats were placed for searcher efficiency trials and the rest were big brown bat (*Eptesicus fuscus*) carcasses obtained from Indiana State University.

Bias trials were conducted throughout the study period at seven placement intervals. Forty-eight bats were placed from zero to seven days prior to searches to estimate the overall probability that a bat carcass was available and detected (Empirical Pi; Table 3). Bat carcasses were placed throughout the study session by a biologist not involved in the carcass search effort, and were randomly placed within a turbine's searchable area. Searchers had no knowledge of the number, placement, or timing of carcasses placed at turbines. Data recorded for each trial carcass included date of placement, species, turbine number, the distance and bearing from the turbine, and date carcass was found. 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, giving searchers 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. 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 1 - October 11, 2017.

Number of Days Prior to Search	Number Placed	Used for Empirical Pi Estimate
0	20	6
1	6	6
2	6	6
3	6	6
4	6	6
5	6	6
6	6	6
7	6	6
Total	62	48

Twenty bat carcasses were monitored to estimate persistence rates. Carcasses were checked on days one, two, four, six, eight, 10, 12, 18, and 24 after placement to calculate average carcass persistence 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 that were estimated to have been killed during the monitoring period;
2) Persistence rates combined with searcher efficiency, expressed as the estimated average probability a bat carcass is expected to be available for detection and was detected by the observers during combined bias trials; and
3) The search 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 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 persistence. Carcasses were placed in the field throughout the search interval and left until they were either found by searchers or removed by some other 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).

Road and pad area is smaller at Phase IV compared to Phases I, II and III, which required a different correction factor in order to accurately estimate bat fatality rates. 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 the carcass-density distribution and search area at each turbine. Data collected from 2012 through 2016 were used to estimate bat carcass-density as a function of distance from turbine. The carcass-density distribution 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. Areas near the turbine tend to have a higher density of bat carcasses than areas farther from the turbine (Huso and Dalthorp 2014) and therefore the search area was combined with the carcass-density distribution. 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.

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 Persistence Rates

Definition of Variables

The following variables were used to calculate carcass persistence rates:

- s the number of carcasses used in persistence trials
- s_c the number of carcasses in persistence 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 persistence trials
- $\bar{t}$ the average time (in days) a carcass remains in the study area before it is removed, as determined by the persistence trials

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

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

Between Years Comparisons

Percent change in casualty rates between 2017 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 1,516 surveys were conducted on roads and pads across 140 turbines from August 1 – October 11, 2017. Overall, 130 bat carcasses and 10 bird carcasses were found during the survey (Table 4; Appendix B).

Species Composition

The most commonly found bat species were both eastern red bat (*Lasiurus borealis*) and silver-haired bat (*Lasionycteris noctivagans*; at 54 carcasses each, totaling 83% of carcasses together), followed by hoary bat (*Lasiurus cinereus*; 12 carcasses, 9.2%) and big brown bat (8 carcasses, 6.2%). Two other species were found: Seminole bat (*Lasiurus seminolus*; 1 carcass, 0.8%) and evening bat (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), and the IDNR was notified of the carcass on September 29, 2017. No Indiana bat or other *Myotis* spp. carcasses were found during the 2017 study (Table 4).

The 10 bird carcasses found during the survey represent 10 individual known bird species (Table 4). No bird species listed as threatened or endangered by the Indiana Department of Natural Resources (INHDC 2017), or the federal Endangered Species Act (ESA) 1973 were found (USFWS 2017).

Table 4. Total number of bird and bat carcasses and the percent composition of carcasses found at the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

Species	Carcasses Found on Plots during Scheduled Searches and Estimated to Have Perished After August 1		Incidental Carcasses at Search Plots Estimated to Have Perished After August 1		Incidental Carcasses Found Outside of Search Plots or Estimated to Have Perished outside of the Fall Migration Season		Total	
	Total	% Comp.	Total	% Comp.	Total	% Comp.	Total	% Comp.
Bats								
big brown bat	4	4.4	0	0	4	10.5	8	6.2
eastern red bat	35	38.5	0	0	19	50.0	54	41.5
evening bat	1	1.1	0	0	0	0.0	1	0.8
hoary bat	9	9.9	0	0	3	7.9	12	9.2
Seminole bat	1	1.1	0	0	0	0	1	0.8
silver-haired bat	41	45.0	1	100	12	31.6	54	41.5
Total Bats	**91**	**100.0**	**1**	**100**	**38**	**100.0**	**130**	**100.0**
Birds								
American goldfinch	1	14.3	0	0	0	0	1	10
American redstart	1	14.3	0	0	0	0	1	10
American robin	1	14.3	0	0	0	0	1	10
chimney swift	0	0	0	0	1	33.3	1	10
mourning dove	1	14.3	0	0	0	0	1	10
red-eyed vireo	1	14.3	0	0	0	0	1	10
red-tailed hawk	0	0	0	0	1	33.3	1	10
ruby-throated hummingbird	1	14.3	0	0	0	0	1	10
Tennessee warbler	1	0	0	0	0	0	1	10
turkey vulture	0	0	0	0	1	33.3	1	10
Total Birds	**7**	**100.0**		**100**	**3**	**100.0**	**10**	**100**

Percentages may not add up to 100 due to rounding

Estimated Time since Death

Most bat carcasses found on search plots were estimated to have been killed the night before the search (42.7%) or two to three days before the search (28.1%; Table 5). More than 95% of bat carcasses had an estimated time of death of less than a week while less than 5% of bat carcasses had an estimated time of death beyond seven days (Table 5). Three bats were found injured and released after further inspection; all three were included in fatality estimates.

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 1 - October 11, 2017.

Estimated Time Since Death	Number of Carcasses	% Composition
Bats		
last night	38	41.3
2-3 days	25	27.2
4-7 days	22	23.9
7-14 days	2	2.2
>2 weeks	0	0.0
>month	1	1.1
unknown	1	1.1
injured	3	3.3

[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 was found from late-August to late-September (August 21 – September 25). The peak in bats found on September 6 was comprised primarily of silver-haired bats (Figure 2).

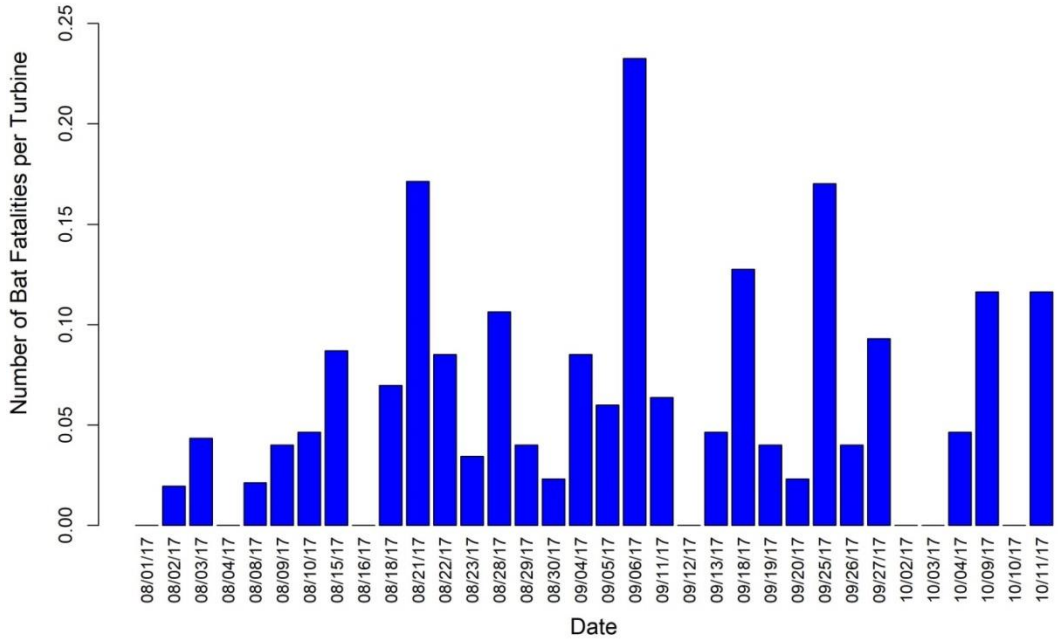

Figure 2. Timing of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

Distribution of Bat Carcasses

A total of 89.1% of bat carcasses were found within 50 m (164.0 ft) of turbines, with the highest percentage (39.1%) of carcasses found between 0 – 10 m (0 – 32.8 ft), followed by almost equal numbers of bat carcasses found between 20 – 30 m (65.6 – 98.4 ft) and 10 - 20 m (32.8 – 65.6 ft) from turbines (21.7% and 19.6% respectively; 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 1 - October 11, 2017.

Distance to Turbine (m)	Number of Carcasses	% Composition
0 to 10	36	39.1
10 to 20	18	19.6
20 to 30	20	21.7
30 to 40	5	5.4
40 to 50	3	3.3
50 to 60	7	7.6
60 to 70	3	3.3
70 to 80	0	0.0

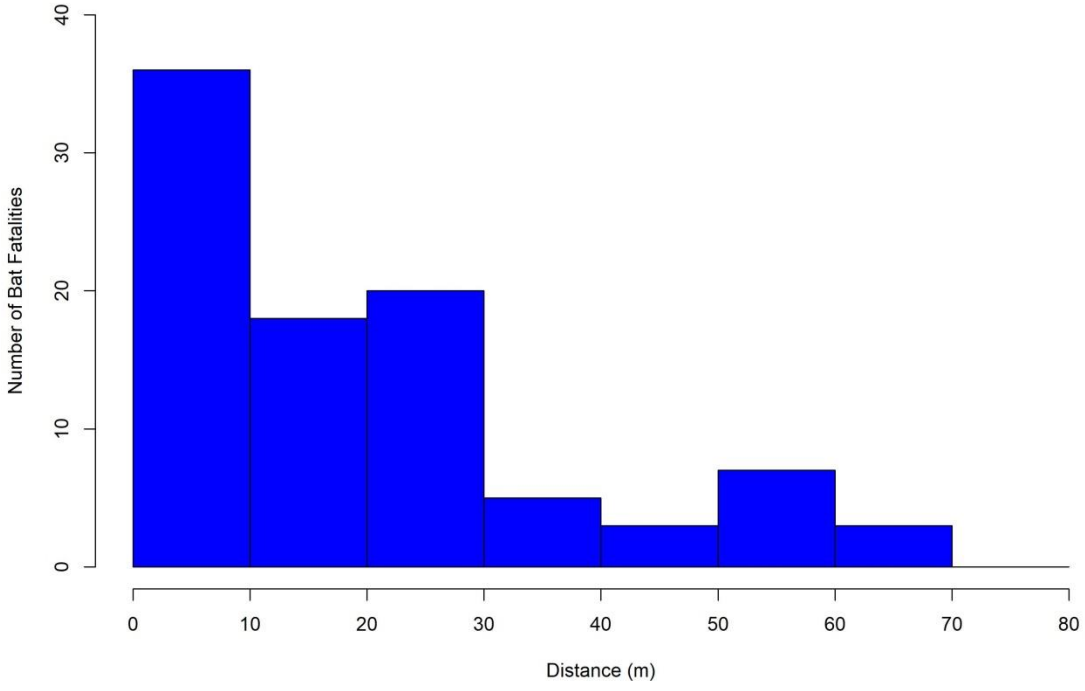

Figure 3. Distribution of distances from turbines of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

Bat Carcasses by Turbine Location

The highest observed casualty rates occurred at the Clipper turbines with 15 carcasses on eight searched turbines, for a rate of 1.88 observed bat carcasses per turbine, followed by Vestas with 30 carcasses found at 39 Vestas turbines (0.77 observed bat carcasses per turbine) (Figure 4). Forty-three bat carcasses were found at 65 Siemens turbines (0.66 observed bat carcasses per turbine) and four bat carcasses were found on 28 GE turbines (0.14 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).

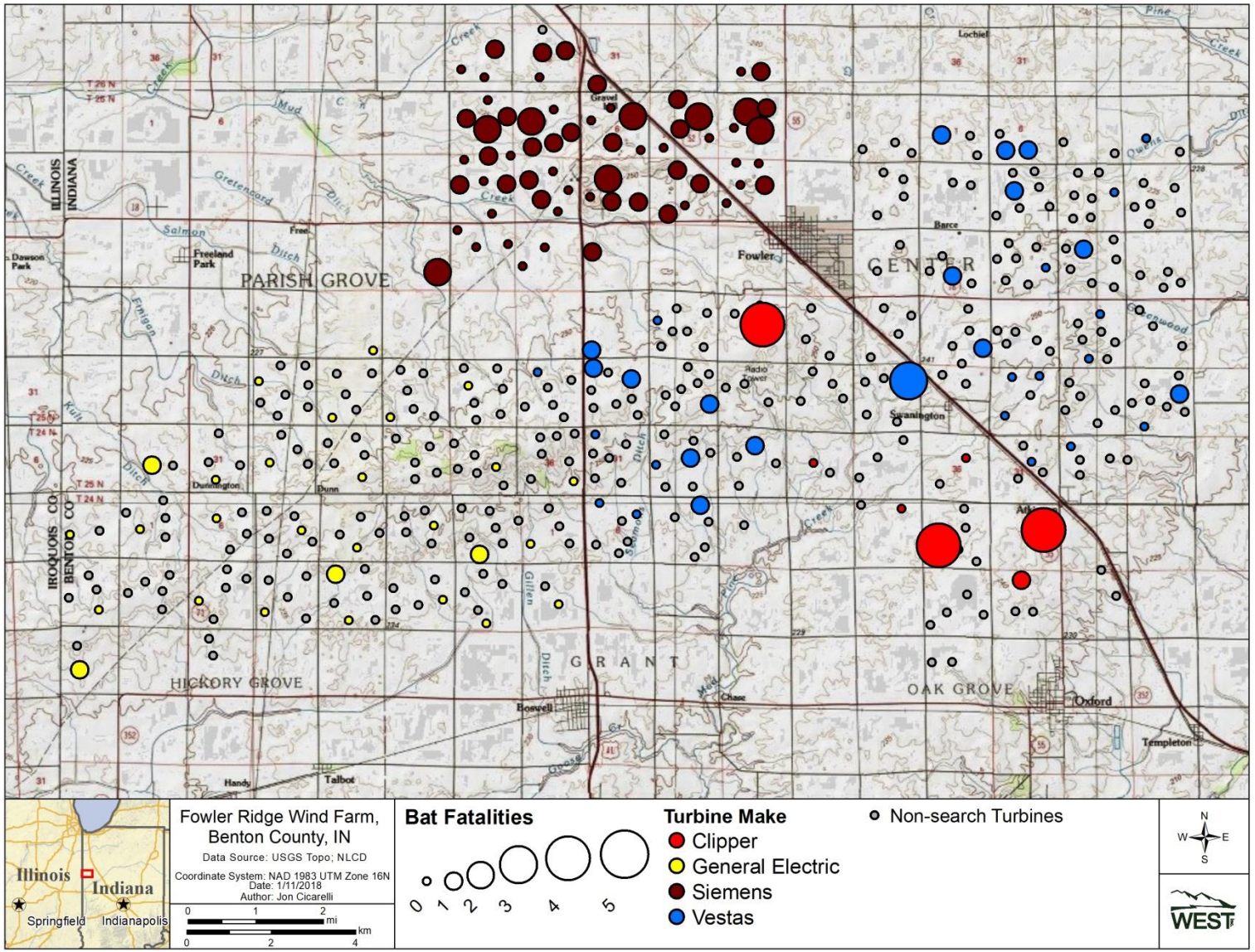

Figure 4. Number of bat carcasses that were found on search plots and were estimated to have been killed during the fall migration period at the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

Bias Trials

Twenty-nine of the 48 trial carcasses placed for bias trials were found at the next scheduled search (Table 7), with no additional bats found after multiple searches, resulting in an overall probability of a carcass being available and detected of 60.4% (Table 7). The probability that a carcass was available and detected in 2017 was lower than in 2016 (70.7%; Good et al. 2017) but similar to most years where weekly searches were completed (2015 [61.0%; Good et al. 2016], 2013 [55.5%; Good et al. 2014], and 2012 [56.7%; Good et al. 2013] and 2010 [51%; Good et al. 2011]).

Table 7. Searcher efficiency based on empirical pi methodology for post-construction casualty monitoring at the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

Number of Days Prior to Search	Number Placed	Number Found on Next Search	Total Found	Percent Found
0	6	6	6	100
1	6	5	5	83.3
2	6	6	6	100
3	6	3	3	50.0
4	6	4	4	66.7
5	6	2	2	33.3
6	6	0	0	0
7	6	3	3	50.0
Total	48	29	29	60.4

A total of 20 bats were used to measure carcass persistence rates. The average length of persistence for bat carcasses in 2017 was 10.7 days. The carcass persistence estimate for 2017 was almost half the rate observed in 2016 (20.07 days, Good et al. 2017), and lower than 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), but almost double the estimate of 2013 (5.8 days; Good et al. 2014).

Adjusted Casualty Estimates

Thirty-eight 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). Ninety-two bat carcasses were included in the casualty estimate, resulting in an observed casualty rate of 0.66 bats per turbine. The observed casualty rate was then divided by the empirical probability of availability and detection (0.60). 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 2017 study was 10.52 bat casualties/turbine/study period (Table 8), or 5.24 bat casualties/MW/study period. The adjusted bat casualty rate was highest at Clipper turbines and Siemens turbines (Table 9).

Table 8. Number of bat casualties per turbine per study period for the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

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		0.66	0.09	0.52	0.81
Empirical pi		0.60	0.05	0.50	0.69
Adjusted number of casualties per turbine		**10.52**	**1.78**	**8.17**	**13.88**

Table 9. Adjusted bat casualty estimates (empirical pi) for different turbine types within the Fowler Ridge Wind Farm from August 1 - October 11, 2017.

	Adjusted Overall Casualty Estimate and 90% Confidence Intervals	
	Mean	CI
	# casualties/turbine/study period	
GE	1.55	0.40 – 3.03
Clipper	20.36	5.62 – 39.36
Vestas	8.35	5.38 – 11.78
Siemens	28.89	21.50 – 38.96
All Turbines	**10.52**	**8.17 - 13.88**
	# casualties/MW/study period	
GE	1.03	0.27 – 2.02
Clipper	8.14	2.25 – 15.74
Vestas	5.06	3.26 – 7.14
Siemens	12.56	9.35 – 16.94
All Turbines	**5.24**	**4.09 – 6.90**

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 2017 casualty estimates from turbines feathered until wind speeds reached 5.0 m/s were 66.3% lower than the road and pad casualty estimates at turbines operating normally in 2010, with an estimated 10.52 bat casualties/turbine/study period (90% CI 8.17 - 13.88).

Uncertainty around bat casualty rate estimates was calculated using 90% CI. Casualty rates from 2017 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 at least a 50% reduction in casualty rate from 2010 to 2017 (Figure 5).

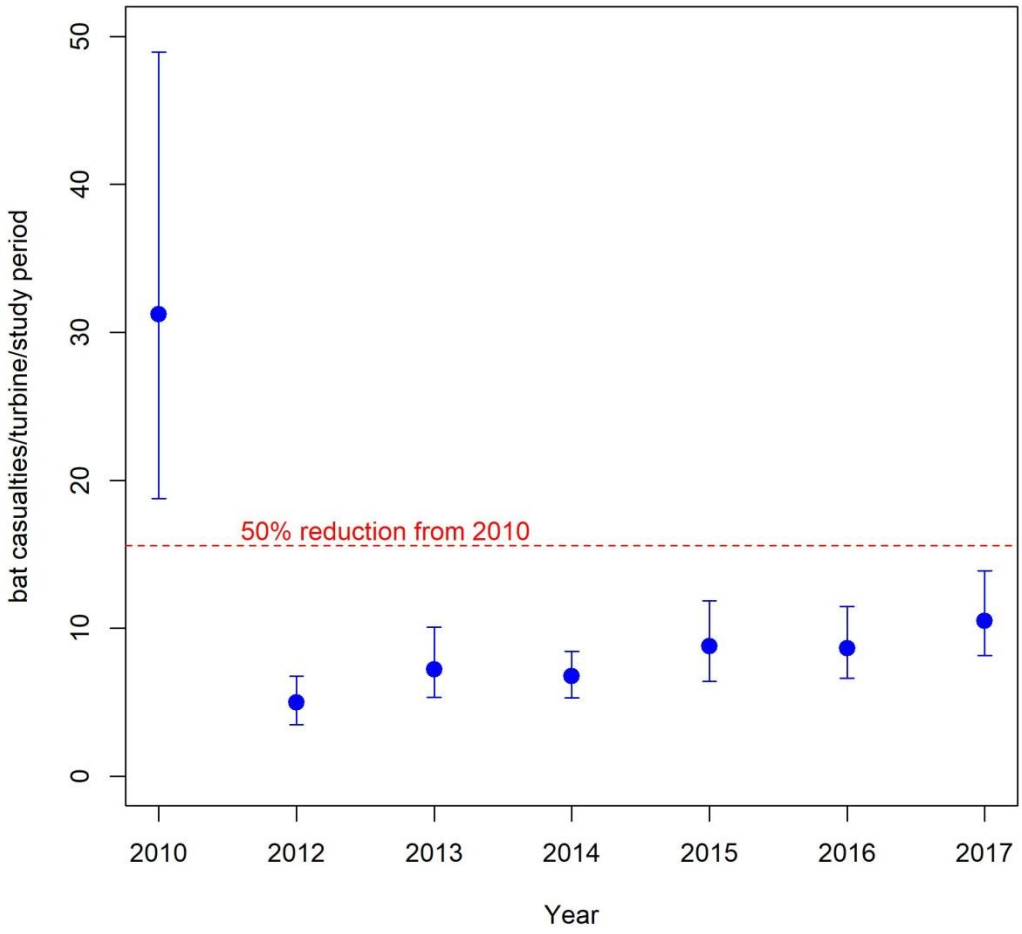

Figure 5. A comparison of estimated bat casualty rates and 90% confidence intervals for Fowler Ridge Wind Farm. The 2010 estimate represents turbines operating at manufacturer cut-in speeds. The 2012-2017 estimates represent data collected at turbines that were feathered below 5.0 m/s. The red dotted 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 2017 was 164.1 bat carcasses. A total of 93 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. The estimated time of death for one bat was changed after the conclusion of the study, and 92 bat carcasses were included in the final fatality estimate.

Figure 6 illustrates the within-season tracking tool that was used to determine if mortality was approaching within-season adaptive management thresholds. The weekly 2017 estimated bat casualty rate shown in Figure 6 was a prediction that was calculated using the 2016 bias trial data. The final 2017 bat casualty estimate was based on 2017 bias trial results. Adaptive Management thresholds were not exceeded at any time during the study, and no changes to minimization efforts were required during 2017.

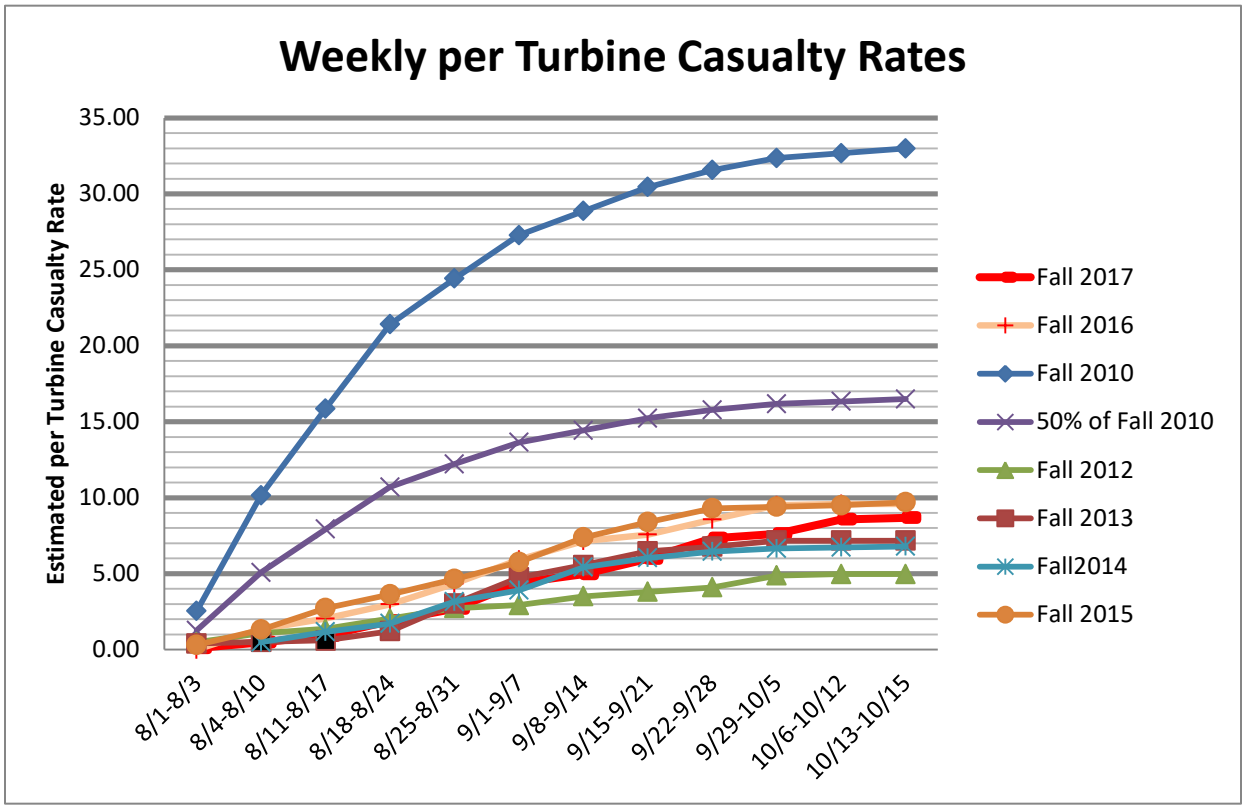

Figure 6. Weekly per turbine casualty rates (number of bat carcasses found per turbine) at the Fowler Ridge Wind Farm in 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 50% of fall 2010. This graph was used to determine if weekly casualty rates were approaching the 50% Adaptive Management Threshold. Fatality rates for 2017 shown above were based on 2016 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 shut down for maintenance.

Table 10. Variables used to calculate the within-season adaptive management threshold for 420 operational turbines in 2017 (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	0.71		Estimated probability of carcass being available and detected based on Fowler 2016 empirical bias trials from weekly road/pad searches; will be adjusted annually for subsequent years
Road & Pad Correction Factor	6.56	26.38	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 2012-2016 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 2017 (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 2017; the within season factor did not include 2017 data.
Predicted Upper Quartile of Number of Bats Found per Searched Turbine during the Period for which Adaptive Management Thresholds are Based	1.80	0.45	Predicted based on estimated casualty rate per turbine (16.7), multiplied by empirical PI (0.71), divided by road/pad correction factor (6.56 or 26.38)
Total Bats Found in One Fall Season Based on Turbines Searched	135.0	29.1	Predicted based on estimated number of bats found per turbine (1.80 or 0.45) multiplied by the number of turbines searched (75 or 65). Calculated value represents Adaptive Management Threshold for 2017
Total Bats Found Threshold	**164.1**		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 2017 was calculated based on the overall estimated bat casualty rate during 2017, and the relative percent that Indiana bat carcasses composed of all bat carcasses found during fall in 2009, 2010, and 2011 (0.16%). A total of 7.1 (90% CI 5.5 – 9.3) Indiana bat casualties were estimated to have occurred in 2017, which is lower than the number of 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% CI of Indiana bat casualties predicted within the HCP.

The end of year adaptive management threshold is equal to the upper bound of the 90% CI of Indiana bat mortality predicted within the HCP. The original HCP assumed a larger number of turbines would be constructed than what was actually built, and the predicted Indiana bat mortality was adjusted based on the actual number of turbines constructed (Table 11). Per the terms of the HCP, no changes to minimization efforts are required for 2018.

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
2017	420	7.1	8.8	10.9	13.4

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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 the Fowler Ridge Wind Farm between July 19 – October 15, 2017

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between July 19 – October 15, 2017.

Date	Common Name	Location	Turbine Type	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?	Included in fatality estimate?
7/19/2017	silver-haired bat	603	Clipper	Yes	Yes	No
8/1/2017	eastern red bat	S41	Siemens	No	Yes	No
8/1/2017	eastern red bat	622	Clipper	No	Yes	No
8/1/2017	eastern red bat	286	Vestas	Yes	No	No
8/2/2017	eastern red bat	110	GE	No	Yes	No
8/2/2017	hoary bat	35	GE	No	No	Yes
8/2/2017	eastern red bat	88	GE	No	Yes	No
8/2/2017	eastern red bat	S9	Siemens	No	Yes	No
8/3/2017	hoary bat	378	Vestas	No	Yes	No
8/3/2017	hoary bat	478	Vestas	No	No	Yes
8/4/2017	hoary bat	624	Clipper	No	Yes	No
8/8/2017	hoary bat	624	Clipper	No	No	Yes
8/9/2017	eastern red bat	S70	Siemens	No	No	Yes
8/9/2017	Seminole bat	61	GE	No	No	Yes
8/10/2017	eastern red bat	77	NA	Yes	No	No
8/10/2017	hoary bat	S28	Siemens	No	No	Yes
8/10/2017	silver-haired bat	S60	Siemens	No	No	Yes
8/11/2017	eastern red bat	640	Clipper	Yes	No	No
8/11/2017	eastern red bat	640	Clipper	Yes	No	No
8/14/2017	eastern red bat	197	Vestas	Yes	No	No
8/15/2017	eastern red bat	348	Vestas	No	No	Yes
8/15/2017	eastern red bat	388	Vestas	No	No	Yes
8/15/2017	eastern red bat	423	Vestas	No	No	Yes
8/15/2017	big brown bat	359	Vestas	No	No	Yes
8/18/2017	eastern red bat	S12	Siemens	No	No	Yes
8/18/2017	eastern red bat	S52	Siemens	No	No	Yes
8/18/2017	eastern red bat	S58	Siemens	No	No	Yes
8/21/2017	big brown bat	309	Vestas	No	No	Yes
8/21/2017	eastern red bat	339	Vestas	No	No	Yes
8/21/2017	eastern red bat	420	Vestas	No	No	Yes
8/21/2017	eastern red bat	420	Vestas	No	No	Yes
8/21/2017	eastern red bat	448	Vestas	No	No	Yes
8/21/2017	eastern red bat	268	Vestas	No	No	Yes
8/22/2017	big brown bat	396	Vestas	Yes	No	No
8/22/2017	eastern red bat	605	Clipper	No	No	Yes
8/22/2017	eastern red bat	S1	Siemens	No	No	Yes
8/22/2017	eastern red bat	S1	Siemens	No	No	Yes
8/22/2017	eastern red bat	S19	Siemens	No	No	Yes

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between July 19 – October 15, 2017.

Date	Common Name	Location	Turbine Type	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?	Included in fatality estimate?
8/23/2017	silver-haired bat	S45	Siemens	No	No	Yes
8/23/2017	eastern red bat	S47	Siemens	No	No	Yes
8/24/2017	hoary bat	603	Clipper	Yes	No	No
8/28/2017	eastern red bat	478	Vestas	No	No	Yes
8/28/2017	eastern red bat	458	Vestas	No	No	Yes
8/28/2017	silver-haired bat	627	Clipper	No	No	Yes
8/28/2017	big brown bat	605	Clipper	No	No	Yes
8/28/2017	silver-haired bat	605	Clipper	No	No	Yes
8/28/2017	eastern red bat	105	GE	Yes	No	No
8/29/2017	eastern red bat	S17	Siemens	No	No	Yes
8/29/2017	eastern red bat	S20	Siemens	No	No	Yes
8/30/2017	silver-haired bat	S41	Siemens	No	No	Yes
8/30/2017	eastern red bat	629	Clipper	Yes	No	No
9/4/2017	silver-haired bat	309	Vestas	No	No	Yes
9/4/2017	silver-haired bat	322	Vestas	No	No	Yes
9/4/2017	eastern red bat	371	Vestas	No	No	Yes
9/4/2017	silver-haired bat	260	Vestas	No	No	Yes
9/5/2017	silver-haired bat	17	GE	Yes	No	No
9/5/2017	silver-haired bat	3	GE	No	No	Yes
9/5/2017	silver-haired bat	S32	Siemens	No	No	Yes
9/5/2017	silver-haired bat	S32	Siemens	Yes	No	No
9/5/2017	eastern red bat	81	GE	Yes	No	No
9/5/2017	silver-haired bat	S33	Siemens	No	No	Yes
9/5/2017	silver-haired bat	634	Clipper	Yes	No	No
9/6/2017	silver-haired bat	S12	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S11	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S14	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S63	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S51	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S51	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S52	Siemens	No	No	Yes
9/6/2017	eastern red bat	S61	Siemens	Yes	No	No
9/6/2017	silver-haired bat	S59	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S56	Siemens	No	No	Yes
9/6/2017	silver-haired bat	S38	Siemens	No	No	Yes
9/7/2017	silver-haired bat	74	GE	Yes	No	No
9/11/2017	eastern red bat	476	Vestas	No	No	Yes
9/11/2017	silver-haired bat	641	Clipper	No	No	Yes

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between July 19 – October 15, 2017.

Date	Common Name	Location	Turbine Type	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?	Included in fatality estimate?
9/11/2017	silver-haired bat	641	Clipper	No	No	Yes
9/12/2017	big brown bat	361	Vestas	Yes	No	No
9/13/2017	silver-haired bat	612	Clipper	Yes	No	No
9/13/2017	eastern red bat	S45	Siemens	Yes	No	No
9/13/2017	silver-haired bat	S24	Siemens	No	No	Yes
9/13/2017	eastern red bat	S48	Siemens	No	No	Yes
9/15/2017	silver-haired bat	422	Vestas	Yes	No	No
9/18/2017	eastern red bat	322	Vestas	No	No	Yes
9/18/2017	eastern red bat	639	Clipper	Yes	No	No
9/18/2017	silver-haired bat	639	Clipper	No	No	Yes
9/18/2017	silver-haired bat	627	Clipper	No	No	Yes
9/18/2017	eastern red bat	285	Vestas	No	No	Yes
9/18/2017	eastern red bat	251	Vestas	No	No	Yes
9/18/2017	silver-haired bat	193	Vestas	No	No	Yes
9/19/2017	silver-haired bat	82	GE	No	No	Yes
9/19/2017	silver-haired bat	S30	Siemens	No	No	Yes
9/20/2017	big brown bat	S13	Siemens	No	No	Yes
9/20/2017	big brown bat	642	Clipper	Yes	No	No
9/26/2017	big brown bat	629	Clipper	Yes	No	No
9/25/2017	hoary bat	458	Vestas	No	No	Yes
9/25/2017	eastern red bat	641	Clipper	No	No	Yes
9/25/2017	hoary bat	641	Clipper	No	No	Yes
9/25/2017	silver-haired bat	624	Clipper	No	No	Yes
9/25/2017	silver-haired bat	631	Clipper	Yes	No	No
9/25/2017	eastern red bat	329	Vestas	No	No	Yes
9/25/2017	silver-haired bat	195	Vestas	No	No	Yes
9/25/2017	hoary bat	224	Vestas	No	No	Yes
9/25/2017	silver-haired bat	605	Clipper	No	No	Yes
9/26/2017	silver-haired bat	612	Clipper	Yes	No	No
9/26/2017	silver-haired bat	482	Vestas	Yes	No	No
9/26/2017	eastern red bat	629	Clipper	Yes	No	No
9/26/2017	silver-haired bat	S7	Siemens	No	No	Yes
9/26/2017	hoary bat	S69	Siemens	No	No	Yes
9/27/2017	eastern red bat	S34	Siemens	No	No	Yes
9/27/2017	eastern red bat	S45	Siemens	No	No	Yes
9/27/2017	silver-haired bat	S61	Siemens	No	No	Yes
9/27/2017	silver-haired bat	267	Vestas	Yes	No	No
9/27/2017	evening bat	S41	Siemens	No	No	Yes

Appendix B. Bat and Bird Casualties Found at the Fowler Ridge Wind Farm Between July 19 – October 15, 2017.

Date	Common Name	Location	Turbine Type	Outside of Search Plot?	Estimated to have perished prior to the evening of July 31?	Included in fatality estimate?
9/26/2017	silver-haired bat	252	Vestas	Yes	No	No
9/30/2017	eastern red bat	628	Clipper	Yes	No	No
9/30/2017	silver-haired bat	627	Clipper	No	No	Yes
10/4/2017	hoary bat	S48	Siemens	No	No	Yes
10/4/2017	eastern red bat	S40	Siemens	No	No	Yes
10/9/2017	eastern red bat	378	Vestas	No	No	Yes
10/9/2017	eastern red bat	448	Vestas	No	No	Yes
10/9/2017	silver-haired bat	627	Clipper	No	No	Yes
10/9/2017	silver-haired bat	329	Vestas	No	No	Yes
10/9/2017	silver-haired bat	329	Vestas	No	No	Yes
10/11/2017	silver-haired bat	S23	Siemens	No	No	Yes
10/11/2017	eastern red bat	S53	Siemens	No	No	Yes
10/11/2017	silver-haired bat	S46	Siemens	No	No	Yes
10/11/2017	silver-haired bat	S37	Siemens	No	No	Yes
10/11/2017	silver-haired bat	S38	Siemens	No	No	Yes
10/13/2017	eastern red bat	359	Vestas	No	No	No[1]

[1] Carcass was found incidentally and after the last scheduled search