Post-Construction Monitoring Studies for the Headwaters Wind Farm Randolph County, Indiana

Final Report

July 2 – October 15, 2019

Prepared for:

EDP Renewables

Attn: Allison Poe

808 Travis Street, Suite 700
Houston, Texas 77002

Prepared by:

Meredith Rodriguez, Andrew Tredennick, and Karl DuBridge

Western EcoSystems Technology, Inc.
408 West 6th Street
Bloomington, Indiana 47404

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EXECUTIVE SUMMARY

EDP Renewables (EDPR) is operating the Headwaters Wind Farm (HWF) in Randolph County, Indiana. HWF became fully operational in 2014 and consists of 100 2.0-megawatt (MW) Vestas V110 wind turbines. This report details the post-construction fatality monitoring studies conducted in accordance with the HWF Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP; TE85617C-0) for Indiana bats and northern long-eared bats.

The HCP identified 10 turbines with summer risk for Indiana bat and/or northern long-eared bat. After the receipt of the ITP and implementation of curtailment reduction, HWF feathered turbine blades at those turbines when wind speeds were below 5.0 meters per second (mps; 16.4 feet [ft] per second) during the summer maternity season (June 25 – July 31) to minimize impacts to summer maternity colonies. All turbines are within the migratory range of Indiana bat and northern-long eared bat. During the fall migration period (August 1 – October 15), HWF feathered turbine blades at all turbines when wind speeds were below 5.0 mps, on nights when temperatures were above 10° Celsius to minimize impacts to migrating Indiana and northern long-eared bats.

Post-construction monitoring was designed to meet a stand alone probability of detection, or *g*, of 0.25 during the fall migration season. Technicians searched 10 turbines with summer risk as road and pad areas to a distance of 100 m from the turbine, once a week, between July 2 to July 30. In the fall, a technician searched 60 turbines as road and pad plots to a distance of 100 m from the turbine. Dog-handler teams searched 35 turbines as cleared plots with a 70 m radius and five turbines as uncleared soy plots with a 70 m radius. All plots were searched once a week between August 5 to October 15, 2019. Searcher efficiency and carcass persistence trials were also conducted during both seasons to correct for detection and scavenger bias.

One Indiana bat was recorded at HWF on September 18, 2019. No northern long-eared bats were found at HWF. The most commonly found species were eastern red bat (50.7%), followed by silver-haired bat (23.1%) and hoary bat (8.9%). Species composition recorded at HWF was similar to previous studies at the Project and other wind facilities in Indiana. Five bats were found during the summer, and 401 bats were found in the fall. Two individuals each of two state-listed endangered species (little brown bat, and evening bat) were also recorded at HWF in the fall. No other state- or federally listed species were recorded. Thirty-seven bird carcasses were recorded; no state- or federally listed birds were found.

The overall bat fatality estimate was 11.74 bats per MW (90% Confidence Interval: 7.55–18.71). Five Indiana bats and one northern long-eared bat fatalities were estimated to have occurred during the monitoring period (M^* at $\alpha = 0.5$). These values fall below the permitted take for each species, meaning the project was in compliance with the ITP. Likewise, the probability that the annual take rate exceeded the thresholds for Indiana bat and northern long-eared bat did not exceed 95%, indicating that no adaptive management actions are necessary at this time.

STUDY PARTICIPANTS

Meredith Rodriguez	Project Manager and Report Compiler
Rhett Good	Senior Reviewer
Karl DuBridge	Field Supervisor
Anna Ciecka	Detection Dog Coordinator
Daniel Riser-Espinoza	Lead Client Analyst
Andrew Tredennick	Statistician
Kevin Murray	Permitted Bat Biologist
Travis Brown	Permitted Bat Biologist
Ashley Matteson	Permitted Bat Biologist
Julia Wilson	Permitted Bat Biologist
Kristen Klaphake	GIS Technician
Ross Bailey	Field Technician
Josephine Lock	Dog handler
Amanda Janicki	Dog handler

REPORT REFERENCE

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INTRODUCTION

Headwaters Wind Farm, LLC (Headwaters), a subsidiary of EDP Renewables North America (EDPR), is currently operating the Headwaters Wind Farm (HWF) in Randolph County, Indiana. Headwaters obtained an Incidental Take Permit (ITP; TE85617C-0) from the US Fish and Wildlife Service (USFWS) dated June 4, 2019, following their approval of the HWF Habitat Conservation Plan (HCP). The HWF HCP details measures to minimize, mitigate, and monitor impacts to the federally endangered Indiana bat (*Myotis sodalis*) and federally threatened northern long-eared bat (*Myotis septentrionalis*).

The HCP identified 10 turbines that are within 1,000 ft of summer maternity colony habitat for Indiana bat and/or northern long-eared bat. All turbines identified as having summer risk to Indiana bats and/or northern long-eared bats were feathered up to 6.9 m per second (mps; 22.6 ft) prior to June 25 to avoid impacts to Indiana bats and northern long-eared bats. HWF feathered turbine blades at those turbines when wind speeds were below 5.0 m (16.4 ft per second) per second during the summer maternity season from June 25 – July 31 to minimize impacts to summer maternity colonies. All turbines are within the migratory range of Indiana bat and northern-long eared bat. During the fall migration period (August 1 – October 15), HWF feathered turbine blades when wind speeds were below 5.0 mps, on nights when temperatures were above 10°Celsius at all turbines to minimize impacts to migrating Indiana and northern long-eared bats, per the HCP. Western EcoSystems Technology, Inc. (WEST) completed a post-construction monitoring study designed to achieve a 25% probability of detecting a single bat carcass (*g* of 0.25).

STUDY AREA

The HWF is in Randolph County, Indiana, less than eight kilometers (km; five miles) southwest of the town of Winchester (Figure 1). HWF lies approximately 341 m (1,119 ft) above mean sea level and has relatively flat topography. Approximately 87% of the nearly 118-square km (29,272-acre) area within HWF is composed of cropland. Corn (*Zea mays*) and soybean (*Glycine max*) are the most common crop types. The next most common landcover is developed areas (e.g., farmsteads) that collectively compose approximately 6% of the site, followed by deciduous forest (5%; Table 1, Figure 1).

The HWF became operational in 2014 and consists of 100 2.0-megawatt Vestas V110 wind turbines that have a 95 meter (m; 311 foot [ft]) hub height and a 55 m (180 ft) blade length.

Table 1. The landcover types, coverage, and composition at the Headwaters Wind Farm, Randolph County, Indiana.

Habitat	Acres	% Composition
Cultivated Crops	25,349	86.5
Developed[1]	1,592	5.4
Deciduous Forest	1,477	5.0
Hay/Pasture	713	2.4
Herbaceous	120	<0.1
Open Water	13	<0.1
Emergent Herbaceous Wetlands	3	<0.1
Evergreen Forest	3	<0.1
Shrub/Scrub	3	<0.1
Total	**29,272**	**100**

Data from 2011 National Land Cover Database

[1]Developed areas include high, medium, and low-intensity developed areas, as well as developed open space.

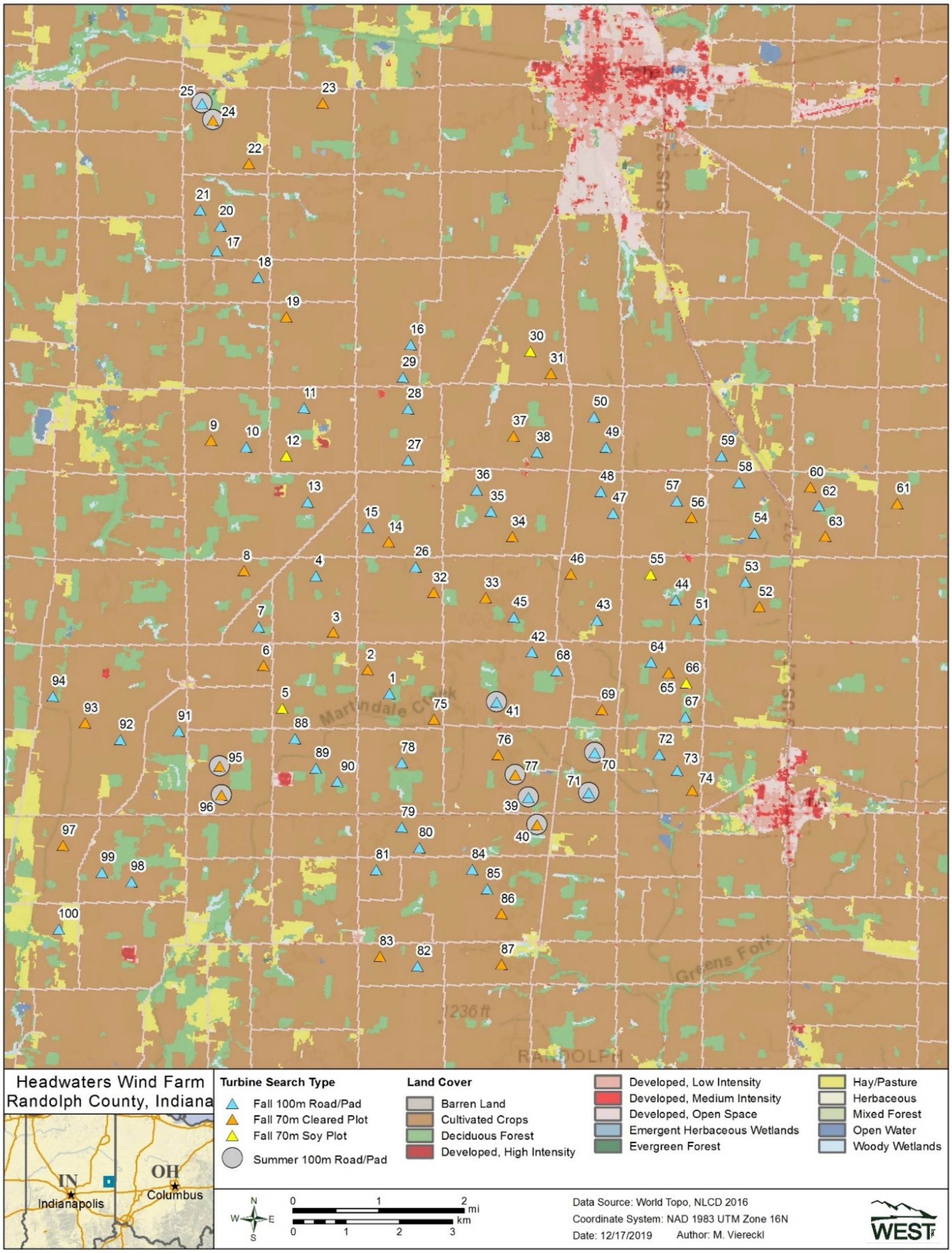

Figure 1. Turbine locations by search type and surrounding land cover at the Headwaters Wind Farm in Randolph County, Indiana

METHODS

The ITP was issued June 4, 2019, and WEST used project-specific data to design a study plan providing a stand-alone *g* of 0.25 in the fall season to meet the monitoring commitments in the HCP. WEST submitted a study plan for the summer to the USFWS on June 14, 2019 and received approval on June 18, 2019 (Marissa Reed, USFWS, pers. comm.), and a final study plan for the fall to the USFWS prior to the study on July 1, 2019 and received approval on July 3, 2019 (Marissa Reed, USFWS, pers comm.). EDPR feathered blades below 5.0 m per s as described within the HCP on June 25, 2019, and summer monitoring began a week later on July 2, 2019.

The main objective of the post-construction monitoring was to document any Indiana bat of northern long-eared bat carcasses that occurred within HWF; however, all bat and bird carcasses that were observed were recorded, per the HCP.

Standardized Carcass Searches

Technicians conducted standardized carcass searches from July 2 to October 15, 2019. All technicians were trained to follow the HWF search protocol, including proper handling and reporting of carcasses. Technicians searched 10 turbines with summer risk as road and pad areas to a distance of 100 m (328 ft) from the turbine, once a week, between July 2 to July 30 (Figure 1).

In the fall, a technician searched the gravel road and pad areas under 60 turbines (road and pad plots) to a distance of 100 m from the turbine. Dog-handler teams searched 35 turbines where crops were regularly mowed within 70-m (230-ft) radius (cleared plots) and five turbines as uncleared soy plots with a 70-m radius (Figure 1). All plots were searched once per week between August 5 and October 15, 2019.

Human Searchers

The technician walked transects spaced 5 m (16 ft) apart at a rate of approximately 45–60 m per minute (min; 148–197 ft/min) on all gravel areas within 100 m of the turbine. The technician scanned the area for fatalities on both sides of the transect out to approximately 2.5 m (8.2 ft) to ensure full visual coverage of each road and pad plot.

Dog-handler Teams

Prior to conducting searches at HWF, handlers trained their detection dogs on the scent of bat carcasses using methods derived from search and rescue programs and drug detection (Kay 2012, Helfers 2017). Dogs were initially trained on cotton scent swabs from bat carcasses, and progressed to bat carcasses at increasing distances. The detection dog coordinator conducted a two day evaluation of each dog handler team; after teams achieved a searcher efficiency of 75% or greater for 30 bats during evaluation trials, they were approved to conduct standardized carcass searches. Because the objective of the study was to document bat species, dogs were not explicitly trained on native bird carcasses; however, all detection dogs alerted on birds in the field, and handlers rewarded bird finds in the field to encourage future alerts to bird carcasses.

Detection dogs used at HWF included a dutch shepherd, Labrador retriever, and border collie mix breed.

Handlers determined the survey start points and the number of transects needed to cover the plot after taking into account wind speed and direction, as well as crop row direction and density (when applicable). Handlers oriented dogs to start searches perpendicular to the wind to maximize scent detection. Both windspeed and crop density can affect scent dispersal across the search area. Transect width varied to maximize detection and was approximately 10 m (32 ft) apart in un-cleared soybean plots and 15 m (49 ft) in cleared plots. Dog handlers rewarded detection dogs with either a food reward or a short play session when dogs alerted to a bird or bat carcass.

Data Collection

Carcass searches began after first light, and ended by 1700 hours. For each scheduled search, technicians recorded the date, start and end times, technician name, turbine number, type of search and if any fatalities were found. When a fatality was found, technicians placed a flag near it and continued the search. The technician returned after searching the entire plot to record information for each fatality on a fatality data sheet, including the date and time, species, sex and age (when possible), technician name, turbine number, measured distance from turbine, azimuth from turbine, location of carcass as Universal Transverse Mercator (UTM) coordinates, habitat surrounding carcass, condition of carcass (i.e., intact, scavenged, dismembered, feather spot [for birds only], injured), and estimated time of death (e.g., less than one day, two days, etc.). Digital photographs were taken of each fatality, including any visible injuries, surrounding habitat, etc. The technician also plotted the location of each fatality on a map of the search area. Carcasses found in non-search areas (e.g., off the graveled area of a road/pad search) were recorded as incidental discoveries and documented following the same protocol for those found during standard searches.

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

- Intact—a carcass that is complete, not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
- Scavenged—an entire carcass that shows signs of being fed upon by a predator or scavenger, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, portion of a carcass, etc.), or a carcass that has been heavily infested by insects.
- Dismembered—an entire carcass that is found in multiple pieces distributed more than 1.0 m (3.3 ft) apart from one another due to scavenging or other reasons.
- Injured—a bat or bird found alive.

For bird carcasses, the following category was also used:

- Feather spot—Ten or more feathers (excluding down), or two or more primary feathers at one location indicating predation or scavenging of a bird carcass.

Bat carcasses were collected under WEST's Native Endangered and Threatened Species Recovery Permit (TE234121-9), and Indiana Special Purpose Salvage Permit (19-096). Technicians placed all bat carcasses in a re-sealable plastic bag labeled with the unique carcass identification number, turbine number, and date, for storage in a freezer on site. Leather and rubber gloves were used to handle all bat carcasses to eliminate possible transmission of rabies or other diseases. Bird carcasses were recorded but left in the field and marked with spray paint to ensure they were not recorded multiple times during surveys. Any bird carcass suspected of being a state- or federally listed species were not spray painted until identification was verified and after consultation with Indiana Department of Natural Resources (IDNR) and USFWS. Any injured birds were evaluated for possible rehabilitation and IDNR was notified. Injured bats were moved to vegetation but were not taken to rehabilitation facilities or euthanized, in accordance with the restrictions of WEST's salvage permit from IDNR.

Carcass Identification and Agency Notification

Identification of bird carcasses were verified by biologists with significant field experience in identification of birds and their feathers. All bat carcasses were identified via photographs within 48 hours by federally permitted bat biologists (TE19208C-0 and TE234121-9). Any state- or federally endangered or threatened carcasses were reported to the appropriate agency within 48 hours. The identifications of all bat carcasses were also verified in hand by a permitted bat biologist (TE13580D-0) at the end of the surveys and delivered to the USFWS Field Office in Bloomington, Indiana on December 20, 2019.

Tissue samples were collected from heavily scavenged or decomposed carcasses that could not be positively identified and sent to the Northern Arizona University School of Forestry and Center for Microbial Genetics and Genomics for identification via genetics.

Bias Trials

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the probability that a carcass was found by searchers. Approximately 20 bat carcasses per plot type (i.e., road and pad, soy plot, and cleared plot) and season were placed during searcher efficiency trials for a total of 89 carcasses. Estimates of searcher efficiency were used to adjust the total number of carcasses found for those missed by technicians, accounting for detection bias in fatality estimates.

Searcher efficiency trials were conducted in the same areas where carcass searches occurred. Searcher efficiency trials were conducted blindly; technicians conducting carcass searches did not know when trials were conducted or the location of the carcasses. Trial carcasses consisted of big brown bat (*Eptesicus fuscus*) carcasses provided by Indiana State University and bat carcasses of eastern red bats (*Lasiurus borealis*), big brown bats, and silver haired bats (*Lasionycteris noctivagans*) that had previously been found on site.

Each trial bat carcass was discreetly marked with a black zip-tie around the upper forelimb for identification as a study carcass after it is found. Carcasses were dropped from waist-height or higher and allowed to land in a random posture. The number and location of trial carcasses found during the subsequent search were recorded, and the number of trial carcasses available for detection during each search was determined immediately after each trial by the person responsible for distributing the carcasses. Searchers had one chance to locate trial carcasses during the first search after carcass placement. Rubber boots were worn by the trial administrator and a random path was taken to and from carcass locations to avoid the possibility of detection dogs following a human scent trail to trial carcasses. The majority of searcher efficiency trials were dropped the morning of searches, but due to weather and maintenance delays, some were dropped a day prior to searches, and were checked to confirm availability the day of searches.

Carcass Persistence Trials

The objective of carcass persistence trials was to estimate the average length of time (in days) a carcass would persist, or be available for detection, in the field. Carcasses could be removed by scavenging, or rendered undetectable by typical farming activities. Estimates of carcass persistence were used to adjust the number of carcasses found for those removed from the study area, thereby accounting for persistence bias in the fatality estimate. Trials were conducted during both seasons to incorporate the effects of varying weather and scavenger densities. Thirty-nine bat carcasses were monitored in persistence trials.

Technicians conducting carcass searches monitored the trial carcasses over a 30-day period according to the following schedule as closely as possible. Carcasses were checked daily for the first 4 days, then on day 7, 10, 14, 20, and 30. Trial carcasses were monitored until they were removed by scavenging or other means, completely decomposed, or at the end of the carcass persistence trial, whichever occured first. At the end of the 30-day period, any evidence of the carcasses that remained was removed from the search plot.

Statistical Analysis

Quality Assurance and 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, technicians were responsible for inspecting data forms for completeness, accuracy, and legibility. Potentially erroneous data were identified using a series of database queries. Irregular codes or data suspected as questionable were discussed with the technician and/or project manager. Errors, omissions, or problems identified in later stages of analysis were traced back to the raw data forms, and appropriate changes were made in all affected steps.

Data Compilation and Storage

A Microsoft® SQL 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.

Fatality Rate Estimation

Carcasses included in the fatality rate estimate were found within the search areas (plots) and had an estimated time of death within the study period. Fatality estimates were calculated by season and plot type using GenEst (a generalized estimator of fatality; Dalthorp et al. 2018, Simonis et al. 2018). To obtain an overall estimate of fatality, each carcass included in the analysis was adjusted for searcher efficiency, carcass persistence, a detection reduction factor (also referred to as "*k*"; see below), and a search area adjustment. Estimates and confidence intervals (CI) were calculated using a parametric bootstrap (Dalthorp et al. 2018) for each individual category listed above.

Ninety percent CIs were calculated for each estimate using parametric bootstrapping (Manly 1997; Dalthorp et al. 2018). Bootstrapping is a computer simulation technique that is useful for calculating variances and CIs for complicated test statistics. One thousand bootstrap samples were used. The lower 5^{th} and upper 95^{th} percentiles of the 1,000 bootstrap estimates were estimates of the lower limit and upper limit of 90% CIs. To obtain overall fatality estimates, statisticians calculated a weighted average across plot types. The number of turbines sampled as a full plot or a road and pad was used as a weight in the averaging calculation.

<u>Searcher Efficiency Estimation</u>

Data collected during searcher efficiency trials were used to estimate the probability that bird and bat carcasses were detected by searchers. Estimates of searcher efficiency were used to adjust carcass counts for detection bias. Searcher efficiency estimated the probability of a carcass being detected by a searcher given the carcass was available to be found. A logit regression model (Dalthorp et al. 2018) was used to obtain estimates of searcher efficiency, while accounting for the detection reduction factor *k*. Potential covariates for the logit regression models included plot type and season. However, season and plot type were confounded, because only road and pads were searched in both summer and fall. Therefore, model selection proceeded in two steps. First, road and pad searches were modeled in isolation to determine if there was an effect of season. Second, after ruling out a season effect for road and pad searches, all searches were modeled with a plot type effect. Model selection was completed using an information theoretic approach known as AICc, or corrected Akaike Information Criteria (Burnham et al. 2002). The best model was selected as the most parsimonious model within two AICc units of the model with the lowest AICc value.

<u>Carcass Persistence Rate Estimation</u>

Data collected during carcass persistence trials were used to estimate the number of days that carcasses remained available to be located by the searcher. Estimates of carcass persistence were used to adjust carcass counts for removal bias. The carcass persistence adjustment estimated the average probability a carcass persisted through the search interval (i.e., the time between scheduled searches). Persistence was modeled using an interval-censored survival regression using exponential, log-logistic, lognormal, and Weibull distributions (Dalthorp 2018, Kalbfleisch and Prentice 2002). Season was the only potential covariate considered in carcass persistence models. The most parsimonious model within two AICc units of the model with the lowest AICc value was selected as the best model.

Detection Reduction Factor

The change in searcher efficiency between successive searches was defined by a parameter called the *detection reduction factor* (*k*) that ranged from zero to one. When *k* is zero it implies that a carcass that was missed on the first search would never be found on subsequent searches. A *k* of one implies searcher efficiency remained constant no matter how many times a carcass is missed. The detection reduction factor was a required parameter for GenEst; however, data were not collected to estimate *k*. Huso et al. (2017) estimated a value of k = 0.67 for bats, and this value was used to calculate bat fatality estimates using GenEst.

Area Adjustment

The search area adjustment accounted for unsearched areas beneath turbines, and was calculated as a probability that ranged from zero to one. The area adjustment was estimated as the product of the unsearched area around each turbine and a carcass-density distribution. A truncated weighted maximum likelihood (TWL) modeling approach (Khokan et al. 2013) was used to estimate the carcass-density distribution. The TWL approach uses weight based probability of detection and the proportion of area searched in each 1.0-m annulus around the turbine, out to the maximum plot extent (i.e., 40 m). Distributions considered were normal, gamma, Gompertz, Rayleigh and Weibull (parameterized according to R Development Core Team [2016] and Thomas [2015]). The proportion of area searched was calculated in a Geographic Information System as the amount of area searched divided by the total area searched at each 1.0-m annulus around the turbine.

Carcasses Excluded from Fatality Estimation

Fatalities were excluded from inclusion in the statistical analysis when the caracass was discovered outside of the spatial and temporal scope of the survey design. For example, carcasses found outside a designated plot were not included in the analysis because the area adjustment accounts for the carcass by adjusting for unsearched areas. Carcasses found prior to the start of surveys (e.g., a carcass found on a plot in the summer that is not searched until the fall) were also excluded because the carcass occured outside of the study period. Note that carcasses found on a plot incidentally were included in the GenEst analysis if that plot has a scheduled search in the future (i.e., GenEst assumes that the carcass would have been found on the next search).

Indiana Bat and Northern Long-eared Bat Take and Detection Probability Estimates

Evidence of Absence

Evidence of Absence (EoA) was used to estimate cumulative take to-date (M^*), mean annual take rate (λ), and the probability that the estimated take rate (λ) exceeded the expected take rate (τ) for both of the covered species for this project, Indiana bat and northern long-eared bat. Estimates were calculated using the EoA R package (**eoa** version 2.0.6), resulting in an analysis consistent with using the Multiple Class and Multiple Years modules of the EoA Graphical User Interface (GUI). Command line functions were used to incorporate key parameters from the GenEst analysis described above, specifically variance associated with the area adjustment. This resulted in an analysis that was slightly more conservative than a standard EoA analysis using the GUI. The analysis was more conservative because more uncertainty is propogated to the final estimate of detection probability, which led to wider confidence intervals on the estimate of overall detection probability. The key parameters needed for the EoA analysis were the detection probability (*g*, and associated uncertainty), the number of carcasses found (*x*), and the density-weighted proportion (or area adjustment; DWP).

Detection probability was estimated by season and plot type, so *g* was estimated separately for those strata. Specifically, 1000 parametric bootstrap samples were drawn from the fitted searcher efficiency (assuming k = 0.67) and carcass persistence models from GenEst (see methods above), and from an area adjustment model fitted using the TWL for the all bat analysis (see methods above).

The seasonality of risk to the covered species was also included as a bias correction in the estimate of detection probability. This was done because *Myotis* activity is unevenly distributed across seasons. The Midwest MSHCP arrival proportions served as the basis for the analysis, with 7% in spring, 36% in summer, and 57% in fall[1]. However, HWF began reduced curtailment pursuant to the ITP on June 25, 2019. Turbines followed USFWS recommendations for avoiding take prior to the issuance of the ITP, therefore, there was no spring risk in 2019. The arrival proportion was collapsed to 39% in summer and 61% in fall[1]. June 25 was the 40th day of the summer period (May 16–July 1); therefore, *Myotis* species were only at risk at HWF for 37 out of 77 days (48%) of the summer. To account for this reduced summer risk, the summer risk value of 39% was reduced by 48% (39% × 48% = approx. 20%) and that reduction was added to the fall risk (61% + 20% = 80%) to achieve 100% risk over summer and fall (20% + 80% = 100%).

In addition to seasonality of *Myotis* arrivals, only a subset of turbines at HWF were identified to have summer risk: 10 out of 100 turbines. Therefore, in 2019, there were 90 turbines with only fall risk and 10 turbines with summer and fall risk. To account for this, the MSHCP arrival proportions were multiplied by the portion of turbines with risk in each season, which allocated the risk in time and space by season (Table 2). The zero value in Table 2 reflects the assumption that 90 turbines do not pose a risk for mortality in the summer. The sum across the four values in Table 2 is 0.82 (0.1 + 0.72 = 0.82), indicating that total risk adds to only 82%. The arrival proportions were then rescaled by dividing by 0.82, leading to total risk that sums to one (0.02/0.82 + 0/0.82 + 0.08/0.82 + 0.72/0.82 = 1). The seasonal arrival proportions used for analysis were: summer = 0.02 (0/0.82 + 0.02/0.82 = 0.024) and fall = 0.98 (0.08/0.82 + 0.72/0.82 = 0.976). These seasonal arrival proportions account for both the arrival phenology of *Myotis* species and the proportion of turbines at the facility that do and do not pose summer risk. Thus, sampling fraction can always be based on the total number of turbines at the facility, regardless of season.

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[1] Summer and fall risk proportions are based on the *Myotis* seasonal arrival proportions from the MSHCP: 0.07, 0.36, and 0.57 for spring, summer, and fall, respectively. Summer risk for HWF was calculated as: 0.36 + (0.07 *.36 / (.36+.57)) = .39. Fall risk at HWF was calculated as: 0.57 + (0.07 *.75 / (.36+.57)) = .61. These calculations apportion the 7% of spring risk to summer and fall based on their relative contributions to the total risk season (summer and fall) at HWF.

Table 2. Arrival proportions by season and proportion of turbines with or without summer risk

Season	Arrival Proportion	Proportion of Risk (Turbines with Summer Risk, n=10 or 10%)	Proportion of Risk (Turbines with Summer Risk, n=90 or 90%)
Summer	0.2	0.2 × 0.1 = 0.02	0 × 0.9 = 0
Fall	0.8	0.8 × 0.1 = 0.08	0.8 × 0.9 = 0.72
Total	**1.0**	**0.1**	**0.72**

To incorporate these values in the EoA analysis, the DWP value for each strata was adjusted by the appropriate season weight. Thus, the area correction value (DWP) accounted for areas not searched in both time (relative to seasonal risk) and space. In other words, for this analysis the DWP is an omnibus bias correction that accounts for the area correction, the sampling fraction, and the seasonal risk profile as described in the HCP. Sampling fraction in the summer was 10 out 100 (0.1) and sampling fraction in the fall was 100 out 100 (1), with the 100 turbines broken out by plot type in the fall so that each stratum received its own sampling fraction.

The 1000 parametric bootstrap samples of searcher efficiency, carcass persistence, DWP (the omnibus bias correction), and a *k* value of 0.67 were used in the **eoa**::`calcg.fixed` function to generate 1000 bootstrap estimates of *g* for each unique combination of plot type and season. This procedure generated a distribution of *g* from which the median and upper and lower 90% CIs were calculated for each strata. Likewise, summing *g* values across strata for each bootstrap replicate yielded a distribution of overall *g*, which was also summarized as the median and 90% CI. These values were then used in the **eoa**::`g2ab` function to compute parameters (*Ba* and *Bb*) for a beta distribution describing the distribution of *g*, which was required for EoA. EoA command line functions were then used to estimate *M** (`postMstar.ab`), mean take rate and its 95% CI (`postL.abCI`), and the probability that $\lambda > \tau$ (`posteriorL.ab`). Appendix B shows how the compliance metrics can be calculated using the EoA Graphical User Interface[2].

<u>Adaptive Management Triggers</u>

The estimates from the EoA analysis were used to test two adaptive management triggers: a short-term test of whether the estimated take rate was on pace to exceed the expected take rate and a long-term test of whether permitted take had been met (Dalthorp and Huso 2015). Both the short- and long-term triggers were tested individually for Indiana bat and northern long-eared bat.

EoA Short-Term Trigger

The EoA short-term trigger is designed as an early warning signal that the project may be on the path to exceeding permitted take (T) by the end of the permit term. The short-term trigger is designed to trigger an adaptive management response in time to prevent the cumulative take

[2] Note that this analysis allows uncertainty in the area correction (DWP) to propogate to the overall detection probability estimate (*g*). Therefore, the results WEST presents will be slightly different than those obtained from the EoA GUI. Specifically, the credible bounds around *g* reported here are wider than those obtained from the EoA GUI, making this analysis more conservative than a standard EoA analysis.

estimate from actuating a response to the long-term trigger test. The short-term trigger tests if the estimated annual take rate (λ) exceeds the expected take rate (τ = T ÷ years in permit) at a confidence level of α = 0.05, per the HCP. The Short-Term trigger is designed to evaluate a rolling window of six years of post-construction monitoring data. If, within any six-year rolling window, the estimated take rate exceeds the expected take rate with 95% confidence, the short-term trigger would be met, indicating that the minimization plan in the HCP may need to be adjusted to ensure that the cumulative take estimate (*M**) remains within the permitted limit over the ITP term. Only one year of data was used in this analysis because 2019 was the first year of monitoring under the ITP.

EoA Long-Term Trigger

The EoA long-term trigger is designed to test if the cumulative take to date is equal to or greater than the pemitted take (T) under the HCP (i.e., test whether cumulative take has met permitted take). Per the HCP, cumulative take to date (*M**) was estimated at a confidence level of α = 0.5 (using the median, or 50th credible bound, of the posterior distrubtion of estimated mortality). If the cumulative take to date at α = 0.5 is less than the total permitted take (*M** < T), then the project is in compliance with the ITP. If the cumulative take to date at α = 0.5 is greater than or equal to the total permitted take (*M** ≥ T), then the take limit has been met and the project must take avoidance measures.

Development of Proposed 2020 Methods

The Evidence of Absence software (function `Mest1b` from version 1.06; documentation from version 1.00: Dalthorp et al., 2014) was used to calculate g under a range of potential plot configurations and search intervals for monitoring in 2020. The value of *g* scales linearly with the proportion of turbines searched, assuming that the probability of mortality and the probability of finding the mortality are equal across turbines (i.e., the turbines are statistically independent). For example, if a particular search regime produces $g = 0.8$ when all turbines are searched, then a search of half the turbines will yield $g = \frac{0.8}{2} = 0.4$. A search of a single turbine at HWF (which has 100 turbines) would yield $g = \frac{0.8}{100} = 0.008$, permitting calculation of any number of turbines, up to 100. With multiple plot configurations, the site-wide *g* is calculated as the sum of each search-type's *g* multiplied by the number of turbines searched under that protocol. A second search regime may yield $g = 0.2$ for all turbines or $\frac{0.2}{100} = 0.002$ for a single turbine. Then, searching 15 of the turbines under the first search regime and 16 of the turbines under the second regime would yield 15 × 0.008 + 16 × 0.002 = 0.152 over the whole 100 turbine facility.

By calculating the single-turbine detection probability under a range of monitoring scenarios, it was possible to screen a large number of monitoring plans that yielded $g = 0.25$ and to choose a protocol that achieved the desired detection probability while reducing search costs. Parameters used for the estimation of *g* in EoA are shown in Table 3. Carcass persistence, searcher efficiency, and the proportion of carcasses in searched area were populated using the GenEst analysis of 2019 data at HWF. The remaining variables could not be estimated using on-site data and were based on best available information.

Table 3. Inputs required by the Evidence of Absence software that were used to estimate g to develop the 2020 post-construction study plan.

Parameter	Abbreviation in Evidence of Absence	Value(s)
Proportion of carcasses in searched area	*phi*	Variable[1]
Searcher efficiency[2]	*F*	Roads and pads = 0.85 Cleared plots = 0.8 Soy plots = 0.55
Fraction to which searcher efficiency is reduced with each successive search	*k*	0.67
Parameters and probability distribution describing carcass removal dynamics	*Scale (β), Shape (α)* *Distribution*	12.081, 0.476 Weibull
Carcass arrival (phenology of fatality)	Spring, Summer, Fall	0.07, 0.36, 0.57
Carcass arrival (rescaled for reduced summer risk at a subset of 10 turbines)	Spring, Summer, Fall	0.10, 0.06, 0.84
Search interval	*days*	14 days in spring 2 days in summer 7 days in fall

[1]Proportion of carcasses in searched area was calculated using the fitted carcass fall density distribution from 2019 monitoring data (as described in this report). Each 1-m annulus of a circular plot was assigned a probability and a proportion of total fall area searched. These values were multiplied to generate annulus-specific probabilities, which were then summed over the total area actually searched to yield a single value for proportion of carcasses in searched area. The value was denoted as “Variable” because *phi* changed with plot search type and the radius of the plot.

[2]Searcher efficiency rates used assumed that dog-handlers would search cleared plots and soy plots, and that human searchers would search roads and pads in all seasons.

RESULTS

Avian and Bat Carcass Surveys

Ten turbines were searched weekly in the summer, and all 100 turbines were searched weekly in the fall, for a total of 1,120 turbine searches across seasons. Seven searches were missed due to turbine maintenance and weather constraints. Four hundred and six bat carcasses and 37 bird carcasses were found during surveys and incidentally (Table 3). The number, species, location, and the fatality estimates adjusted for searcher efficiency and carcass persistence, and area adjustment biases using GenEst are discussed below, and further details are presented in Appendix A.

Species Composition

One Indiana bat was recorded at Turbine 99 at HWF on September 18, 2019. Turbine 99 is not within 1000 ft of summer maternity colony habitat. The Indiana bat was reported to USFWS on

September 19 and had an estimated time of death of zero to one day prior. The carcass was dismembered, preventing assignment of sex to the carcass. The carcass was delivered to the USFWS office on September 20. No northern long-eared bat carcasses were found during the study.

Five bats were found in the summer, and 401 bats were found in the fall. The most commonly found bat species were eastern red bat (*Lasiurus borealis*; 206 carcasses; 50.7%) silver-haired bat (*Lasionycteris noctivagans*; 94 carcasses; 23.1%), and big brown bat (56 carcasses; 13.8%). Thirty-six hoary bat (*L. cinereus*; 8.9%) and seven seminole bat (*Lasiurus seminolus*; 1.7%) were also found (Table 4).

Two little brown bats (*Myotis lucifugus*) were recorded at HWF on September 17 and September 25, 2019, at turbines 64 and 30. The little brown bat is state-endangered and the carcasses were reported to IDNR on September 18 and 26, respectively. Per the HCP, the USFWS was also notified, and the carcasses were taken to the USFWS office in Bloomington on September 20 and 27. Two evening bats (*Nycticeius humeralis*) were recorded at HWF on August 28 and September 4, 2019. The evening bat is state-endangered and the carcasses were reported to the IDNR on August 29 and September 17, respectively.

One bat carcass, which consisted mainly of bone and fur, was identified as an unknown migratory tree bat due to the presence of frosted tips on its fur (hoary bat, eastern red bat, or silver-haired bat (Whitaker and Mumford 2009). No *Myoti*s sp. occurring in Indiana have frosted tips; thus they were eliminated from the list of potential species .

Over the course of the summer and the fall, 11 heavily scavenged bats (e.g., wing membrane only, bones, or partial carcasses) were sent off for identification via DNA analysis; none were identified as state- or federally listed species. All were identified as common species, including eastern red bat, big brown bat, hoary bat, and silver-haired bat.

Thirty-seven birds were recorded, belonging to 11 species (Table 4). Six birds could not be identified to species; two were found as feather spots and four could not be identified due to their decomposition. One of the unknown birds was an unknown large bird and was documented as a feather spot consisting of large, mostly white body feathers. One feather had distinct brown bars indicating it was most likely a *Buteo* species and did not have potential to be either a bald or golden eagle, which have body feathers characterized by both splotches and solid colors (Scott and McFarland 2010). The most commonly found bird species was horned lark (*Eremophila alpestris*; 35.1%; Table 4). No state- or federally listed bird species were recorded.

Weather Patterns Preceding Myotis Fatalities

Three *Myotis* carcasses were found during the survey period, including one Indiana bat and two little brown bats. The Indiana bat and one little brown bat had an estimated time of death of zero to one day prior. The second little brown bats had an estimated time of deaths two to three days prior. Wind speed and temperature data from on-site weather stations were plotted for all possible nights of death based on the estimated times of death for each carcass (Figure 2). Wind speed varied between approximately 2.5 mps to 9.0 mps on the two nights preceding the discovery of the Indiana bat. Temperature varied between approximately 15–25°Celsius (59–77° Fahrenheit; Figure 2). Temperature and wind speed were more variable across the nights preceding the discovery of the little brown bats (Figure 2).

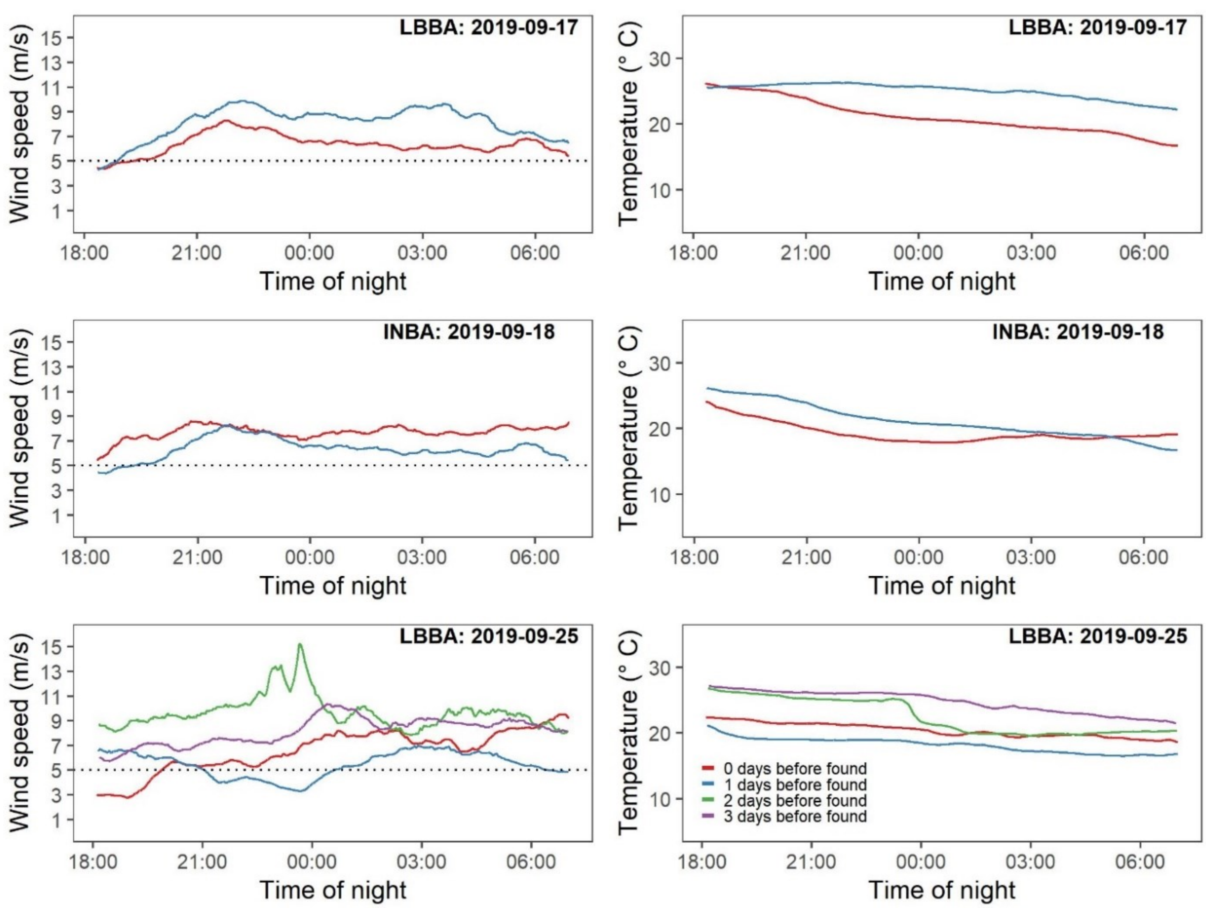

Figure 2. Temperature and wind speeds proceeding *Myotis* carcass discoveries at the Headwaters Wind Farm, September 17, 18, and 25, 2019.
Note: LBBA denotes little brown bat, and INBA denotes Indiana bat. Plots show time series of wind speed and temperature at 15 second intervals, starting 30 minutes before sunset and ending 30 minutes after sunrise. The horizontal dashed line in the wind speed panels displays the curtailment threshold of 5.0 meters per second..

Carcasses for Analysis

Twenty-four of the 406 bats found during the summer and fall monitoring seasons were excluded from fatality estimates: two bat carcasses were excluded from analysis because they were found off plot, for example, outside the graveled search area of a turbine that was searched only as a road/pad. Another 22 bats were excluded because their estimated time of death was prior to the start of surveys for each season (Table 4). Estimates of bird fatalities were not calculated.

Table 4. Total number of carcasses and percent composition of carcasses discovered at the Headwaters Wind Farm from July 2, 2019 to October 15, 2019.

	Included in Fatality Estimates		Outside Plot*		Outside Study Period*		Total	
Species	Total	%	Total	%	Total	%	Total	%
brown-headed cowbird	0	0	0	0	0	0	1	2.7
chimney swift	0	0	0	0	0	0	1	2.7
golden-crowned kinglet	0	0	0	0	0	0	1	2.7
horned lark	0	0	0	0	0	0	13	35.1
killdeer	0	0	0	0	0	0	2	5.4
mourning dove	0	0	0	0	0	0	1	2.7
purple martin	0	0	0	0	0	0	1	2.7
red-eyed vireo	0	0	0	0	0	0	1	2.7
rock pigeon	0	0	0	0	0	0	1	2.7
red-tailed hawk	0	0	0	0	0	0	5	13.5
turkey vulture	0	0	1	100	0	0	4	10.8
unidentified flycatcher	0	0	0	0	0	0	1	2.7
unidentified large bird	0	0	0	0	0	0	1	2.7
unidentified passerine	0	0	0	0	0	0	2	5.4
unidentified swallow	0	0	0	0	0	0	1	2.7
unidentified warbler	0	0	0	0	0	0	1	2.7
Overall Birds*	**0**	**0**	**1**	**100**	**0**	**0**	**37**	**100**
big brown bat	48	12.6	1	50.0	7	31.8	56	13.8
eastern red bat	198	51.8	0	0	8	36.4	206	50.7
evening bat	2	0.5	0	0	0	0	2	0.5
hoary bat	29	7.6	0	0	7	31.8	36	8.9
Indiana bat	1	0.3	0	0	0	0	1	0.3
little brown bat	2	0.5	0	0	0	0	2	0.5
Seminole bat	7	1.8	0	0	0	0	7	1.7
silver-haired bat	93	24.3	1	50.0	0	0	94	23.2
tri-colored bat	1	0.3	0	0	0	0	1	0.3
unidentified migratory tree bat	1	0.3	0	0	0	0	1	0.2
Overall Bats	**382**	**100**	**2**	**100**	**22**	**100**	**406**	**100**

Timing and Distribution of Bat Carcasses

The majority of bat fatalities were recorded in the fall (Table 5). Summer bat fatalities peaked the week of July 16, when three of the four bat carcasses included in analysis for summer were found (Figure 3a). Fall bat fatalities demonstrated two peaks (Figure 3b). The first, in mid to late August, was predominantly composed of eastern red bats. The second, in mid to late September was predominantly eastern red bats and silver-haired bats. Only big brown bats, hoary bats, and eastern red bats were recorded in the summer.

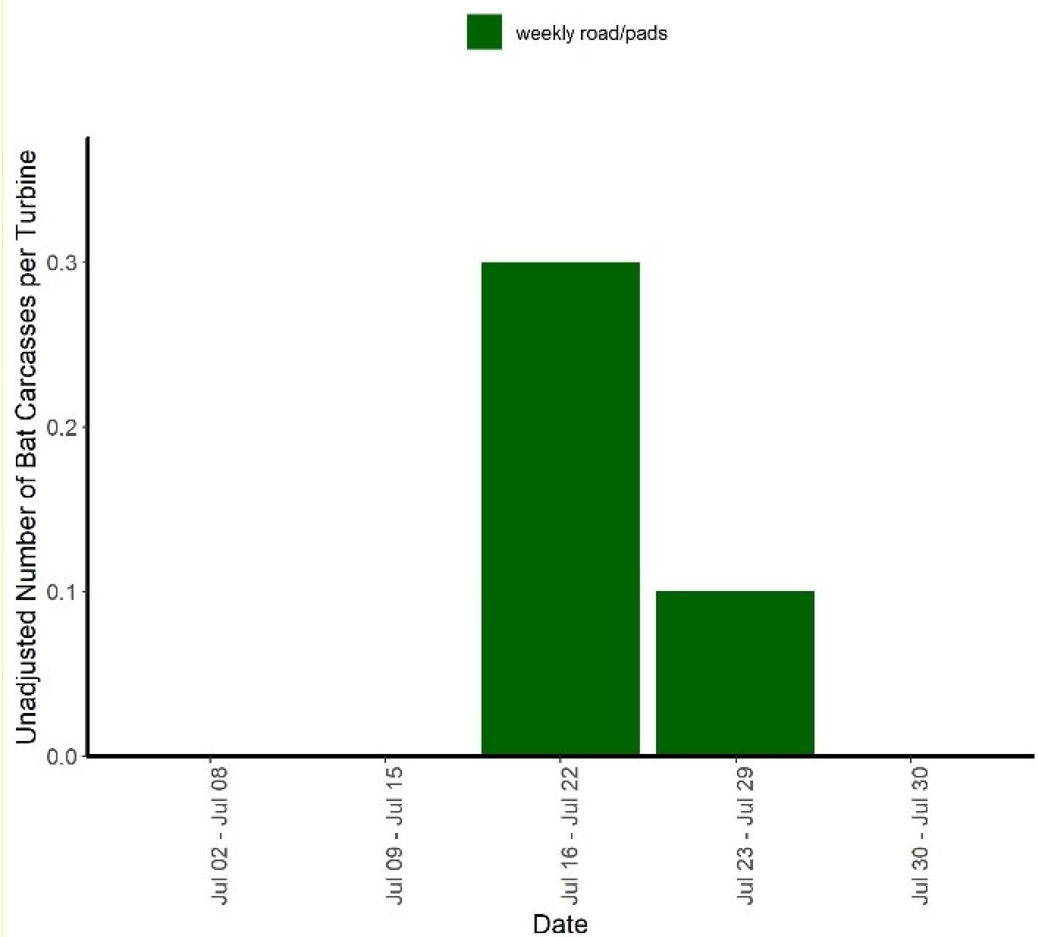

Figure 3a. Timing of bat carcass discoveries at the Headwaters Wind Farm from July 2 – July 30, 2019 that were included in fatality estimates.

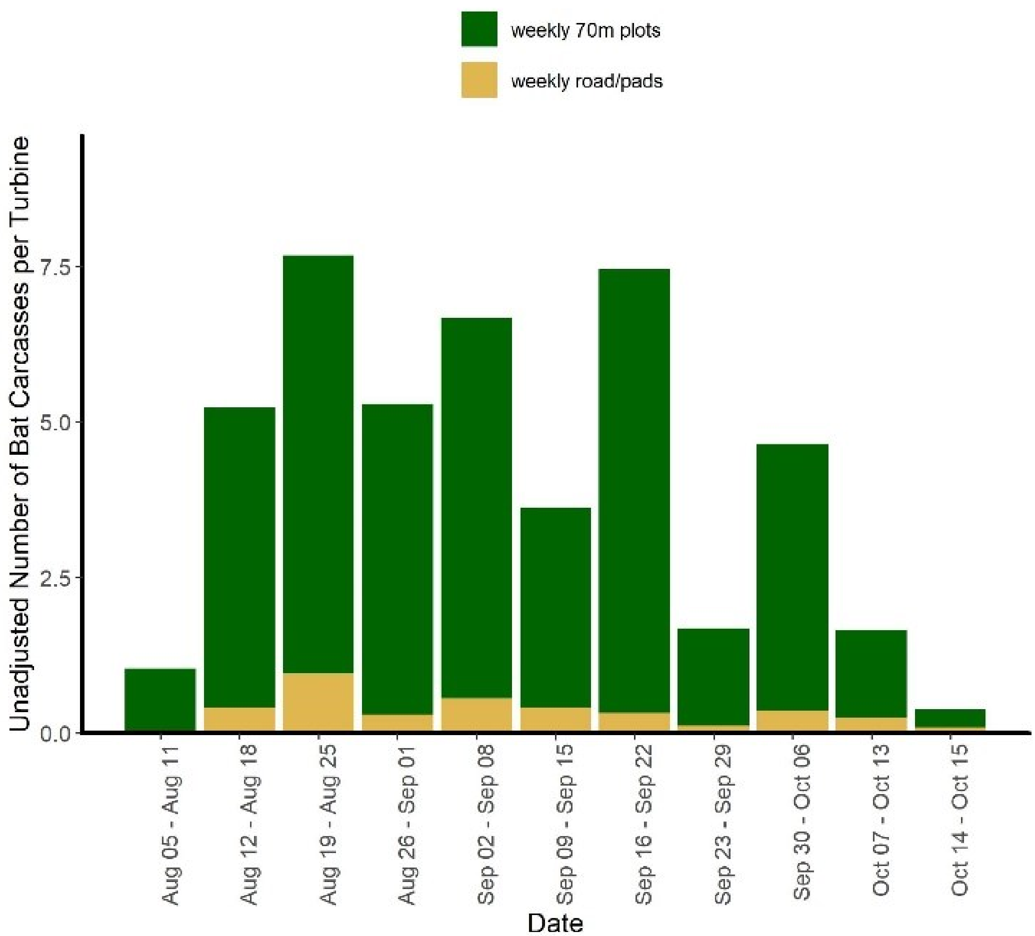

Figure 3b. Timing of bat carcass discoveries at the Headwaters Wind Farm from August 1 – October 15, 2019 that were included in fatality estimates.

Table 5. Species composition by season for bat carcasses[1] found at the Headwaters Wind Farm from July 2, 2019 – October 15, 2019.

	Summer		Fall	
Species	**# of Carcasses**	**% Composition**	**# of Carcasses**	**% Composition**
eastern red bat	2	50	196	51.9
silver-haired bat	0	0	93	24.6
big brown bat	0	0	48	12.7
hoary bat	2	50	27	7.1
Seminole bat	0	0	7	1.9
evening bat	0	0	2	0.5
little brown bat	0	0	2	0.5
Indiana bat	0	0	1	0.27
tri-colored bat	0	0	1	0.27
unidentified migratory tree bat	0	0	1	0.27
Total	**4**	**100**	**378**	**100**

[1] This table only includes bat carcasses included in the Gen-Est fatality estimate.

Carcasses by Turbine Location

The number of bats found per turbine ranged from zero to two in the summer (Figure 4), and from zero to 26 bats per turbine in the fall (Figure 5). The highest numbers of bats were found at plots searched as 70 m cleared plots in the fall. Twenty-six bats were found at Turbine 61, which was searched as a cleared plot in the fall. At roads and pads and 70 m soy plots, the number of bats found per turbine varied between zero to five (Figure 5). No bats were found at 20 turbines, 19 of which were searched as roads and pads and one as a 70 m soy plot (Figure 5). Bats were found throughout HWF.

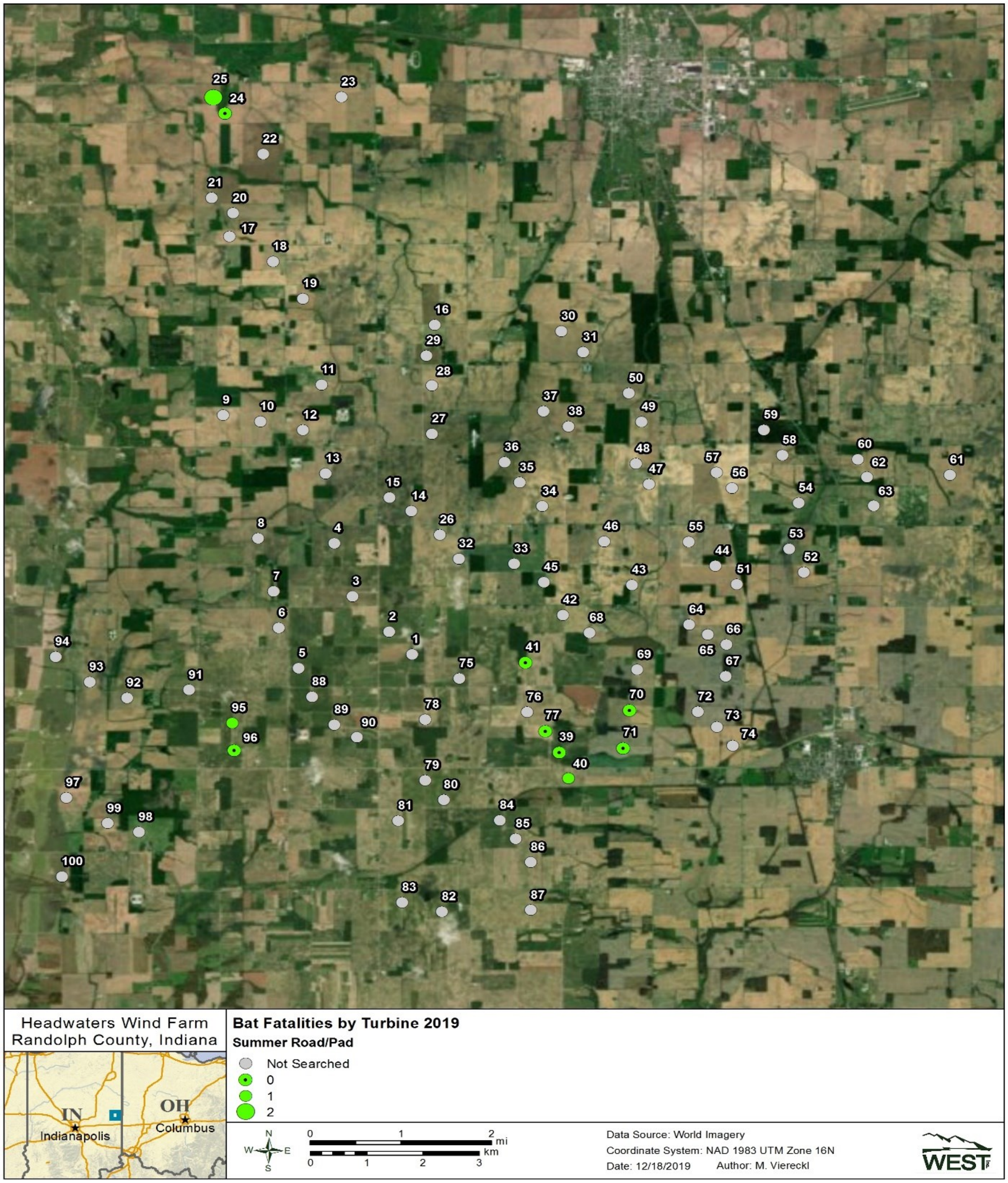

Figure 4. Location of bat carcasses found within search plots at the Headwaters Wind Farm from July 2 – July 31, 2019 that were included in fatality estimates.

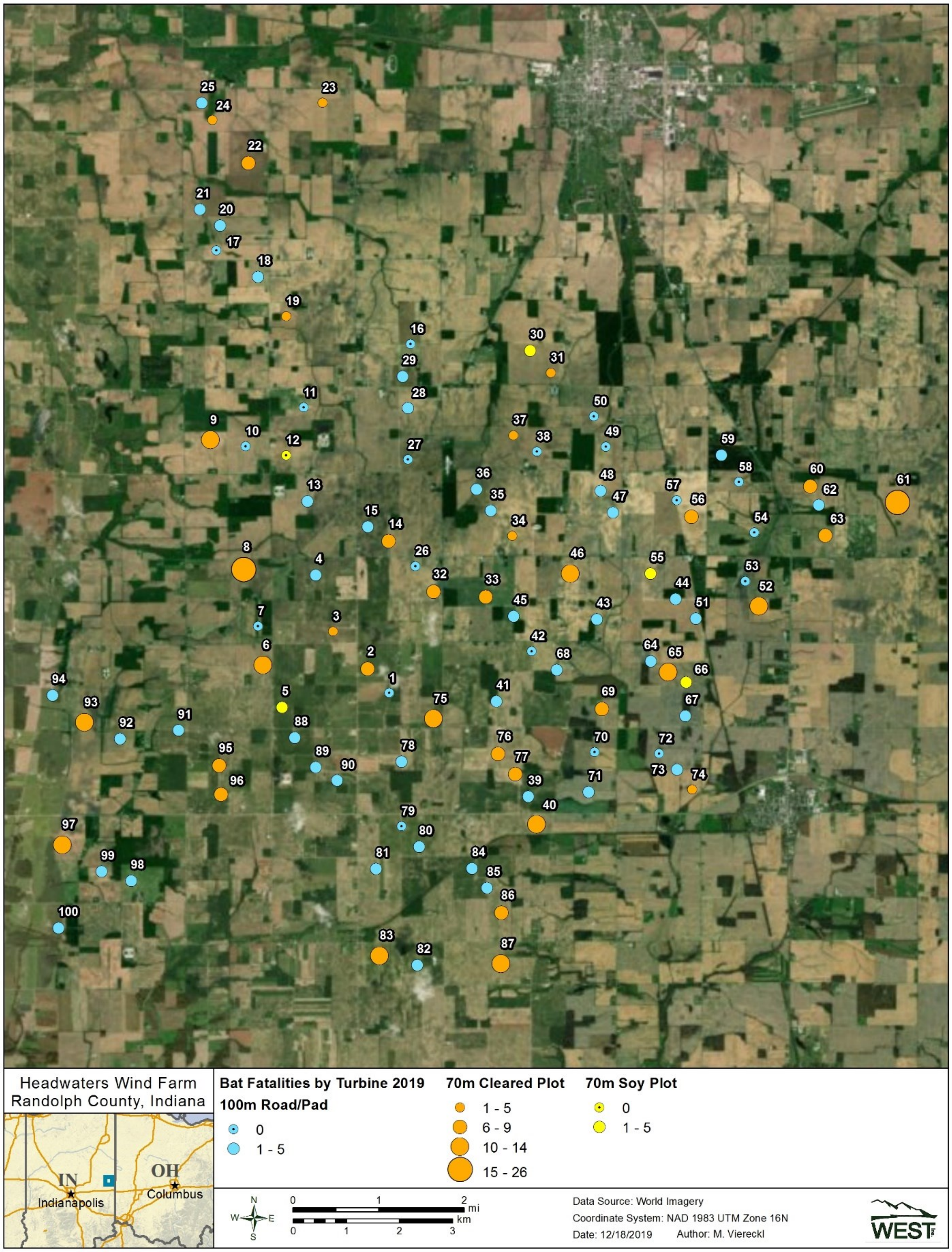

Figure 5. Location of bat carcasses found within search plots at the Headwaters Wind Farm from August 1 – October 15, 2019, that were included in fatality estimates.

Searcher Efficiency Trials

Eighty-nine bats were placed for searcher efficiency trials, and 78 were available for search teams to find across all seasons and plot types. Searcher efficiency rates ranged from 55.0% in soy plots to 88.9% on cleared plots by dog teams, and averaged 85% by humans on roads and pads (Table 6). Searcher efficiency was modeled using the best fit logit regression model to determine if searcher efficiency varied by plot type or season. As described in the methods, initial modeling determined that searcher efficiency did not vary substantially across season. The best-fit model supported the inclusion of plot type as a covariate (Table 7). Searcher efficiency ranged from 0.55 (90% Confidence Interval [CI]: 0.37, 0.72) in soy plots to 0.89 (90% CI: 0.70, 0.96) on cleared plots (Table 8).

Table 6. Searcher efficiency results at the Headwaters Wind Farm as a function of plot type, July 2, 2019 to October 15, 2019.

Plot Type	Number Placed	Number Available	Number Found	% Found
Soy	25	20	11	55.0
Cleared	22	18	16	88.9
Roads and Pads	42	40	34	85
Overall	**89**	**78**	**61**	**78.2**

Table 7. Searcher efficiency logit regression models for bats, small birds and large birds from the searcher efficiency trials at Headwaters Wind Farm July 2, 2019 to October 15, 2019.

Covariates	AICc	DeltaAICc
Plot Type	80.22	0*
No covariates	83.84	3.62

*model chosen for analyses

Table 8. Modeled searcher efficiency rates for bats by search type calculated using a logit regression model for the Gen-Est estimator at the Headwaters Wind Farm, July 2, 2019 to October 15, 2019.

Plot Search Type	Estimated Searcher Efficency (%)	90% Confidence Interval
Soy	0.55	0.37 – 0.72
Cleared	0.89	0.70 – 0.96
Roads and Pads	0.85	0.73 – 0.92

Carcass Persistence Trials

Thirty-nine carcasses were placed to estimate carcass persistence. Carcass persistence was modeled using the best fit logit regression model to determine if carcass persistence varied by season. The best fit model for carcass persistence rates was an intercept-only model with a Weibull distribution, which suggests that bat carcass persistence rates did not vary by season (Figure 6; Table 9). The estimated median carcass persistence time was 5.75 days. Based on the estimated arrival times of all bat carcasses included in the GenEst fatality estimate, the average probability that a carcass persisted through a 7 day search interval was 0.61 (90% CI: 0.49, 0.73).

Table 9. Carcass persistence models and covariates for bats at the Headwaters Wind Farm, July 2, 2019 to October 15, 2019 (n = 30).

Shape Covariates	Scale Covariates	Distribution	AICc	Delta AICc
Season	No Covariates	loglogistic	123.97	0
Season	No Covariates	lognormal	124.29	0.32
Season	No Covariates	Weibull	124.62	0.65
Season	Season	Weibull	125.14	1.17
Season	Season	loglogistic	125.81	1.84
No Covariates	No Covariates	Weibull	125.87	1.90*
Season	Season	lognormal	126.24	2.27
No Covariates	No Covariates	lognormal	126.70	2.73
No Covariates	No Covariates	loglogistic	126.76	2.79
No Covariates	Season	Weibull	126.84	2.87
No Covariates	Season	lognormal	129.09	5.12
No Covariates	Season	loglogistic	129.16	5.19
Season	NULL	exponential	134.88	10.91
No Covariates	NULL	exponential	139.21	15.24

*Selected model

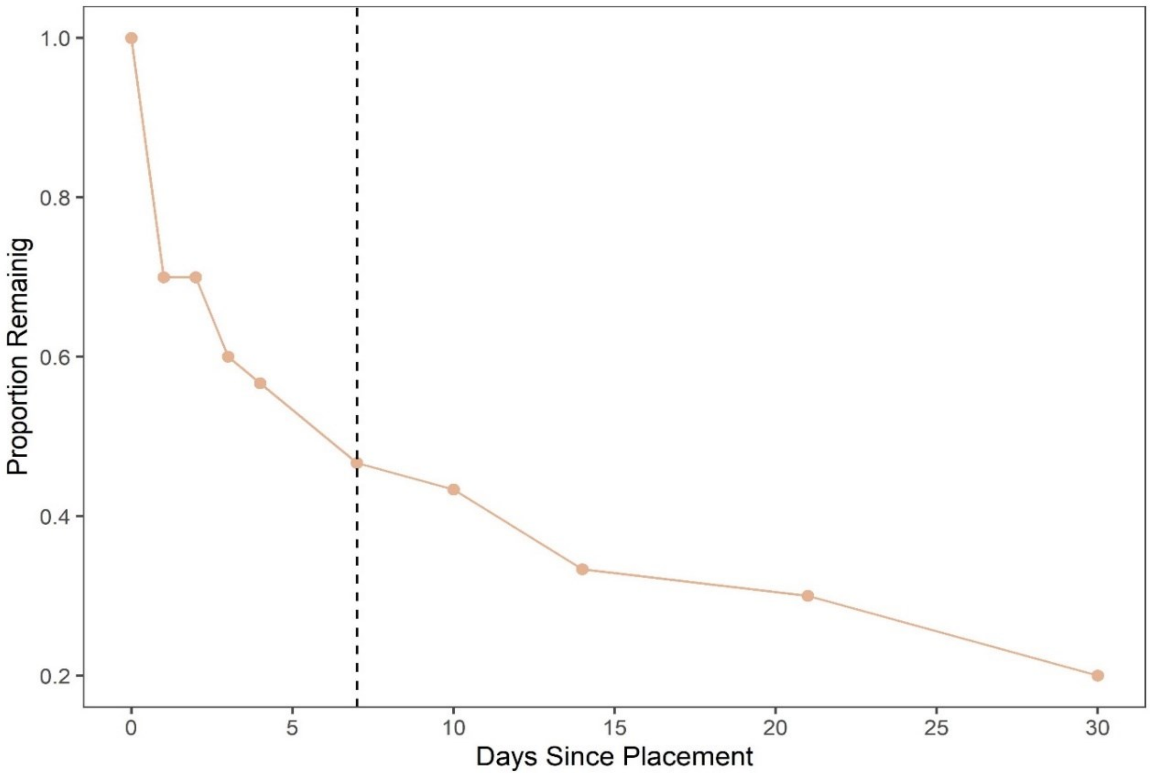

Figure 6. Persistence of carcasses through the 30-day carcass persistence trials at the Headwaters Wind Farm from July 2 – October 15, 2019. Note: Search interval is depicted as a dotted line.

Area Correction

None of the plots had any routinely unsearchable areas due to trees, fences, or other obstructions. The TWL area correction for bats in the fall was calculated using a Gompertz distribution, as 0.80 at full plots and 0.12 at roads and pads (Tables 10 and 11; Figure 7).

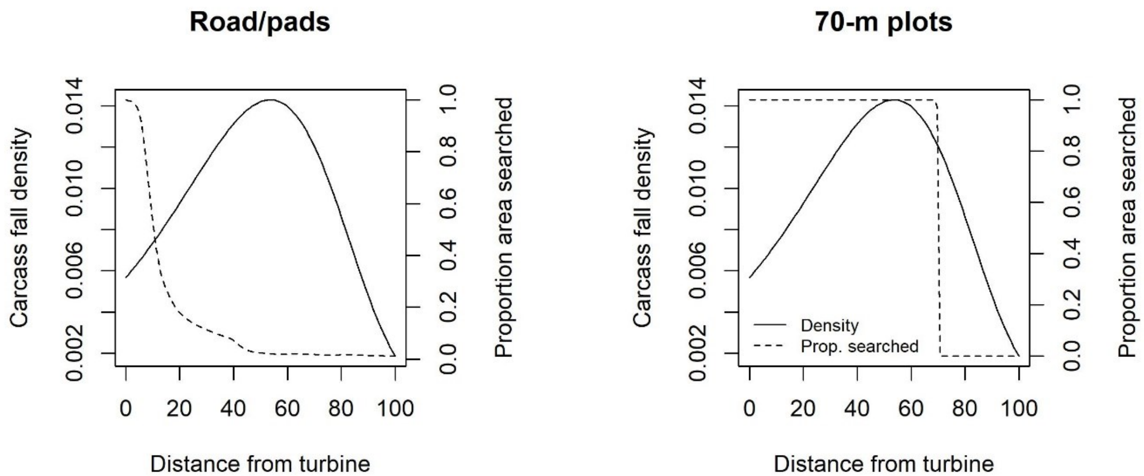

Figure 7. Density of bat carcasses per area searched at all roads and pads, 70 m soy, and 70 m cleared plots at the Headwaters Wind Farm from July 2 – October 15, 2019, that were included in fatality estimates.

Table 10. Search area adjustment models for bats from the Headwaters Wind Farm, July 2, 2019 to October 15, 2019.

Distribution	AICc	Delta AICc
Gompertz	18,454.77	0*
normal	18,490.43	35.66
Weibull	18,571.30	116.52
gamma	18,782.28	327.51

* Selected model

Table 11. Truncated weighted maximum likelihood search area adjustment estimates for the Headwaters Wind Farm, July 2, 2019 to October 15, 2019.*

Plot Type	Distribution	Parameter 1	Parameter 2	Area Correction
70 m plot	Gompertz	0.03	0.01	0.80
Road and pad	Gompertz	0.03	0.01	0.12

N=382 bats.

Adjusted Overall Bat Fatality Estimates

Overall fatality estimates were 11.74 bats per MW (90% CI: 7.55–18.71; Table 12). Fatality estimates for bats were lower in summer than fall (Table 12). Only four bat carcasses found in the summer were found on plots and estimated to have occurred during the monitoring period,; therefore, due to the low sample size, CIs could not be calculated for the summer.

Table 12. Fatality rates by season, per turbine and per MW for studies conducted at the Headwaters Wind Farm, July 2, 2019 to October 15, 2019.

	Per Turbine Estimates		Per MW Estimate	
Season	**Estimate**	**90% CI**	**Estimate**	**90% CI**
Summer	6.27	N/A	3.14	N/A
Fall	17.11	12.04 - 25.27	8.55	6.02 - 12.63
Overall	**23.49**	**15.09 - 37.42**	**11.74**	**7.55 - 18.71**

Indiana Bat and Northern Long-Eared Bat Take Estimates

<u>EoA Framework</u>

One Indiana bat carcass was found during the monitoring season and zero northern long-eared bat carcasses were found.

The 2019 fall monitoring effort was designed to reach a *g* of 0.25. Assuming 100% of risk was in the fall, the 90% confidence interval of *g* achieved during the fall of 2019 was 0.16–0.28 with a median of 0.22. After incorporating summer risk and the lower level of summer monitoring, the overall *g* achieved for the 2019 monitoring period was 0.21 (95% CI = 0.15 – 0.28). The expected value of g =0.25 falls within the 90% confidence interval for both the fall and overall monitoring period, indicating there is no statistical difference between the target *g* and realized *g* for the fall or overall monitoring effort. Stratum-specific detection rates and associated components are shown in Tables 13 and 14. Average values of parameters used in the EoA analysis are in Table 15.

Table 13. Components of each stratum's contribution to the facility-wide detection probability (*g*) for the Headwaters Wind Farm, July 2 – October 15, 2019.

Season	Plot Type	Detection Probability/Stratum[a]	Temporal Risk Fraction[b]	Sampling fraction	Area Correction	Contribution to facility-wide Detection Probability (g)[c]
Fall	cleared	0.56	0.98	0.35	0.81	0.156
Fall	full plot (soy)	0.42	0.98	0.05	0.81	0.017
Fall	road/pad	0.55	0.98	0.60	0.12	0.04
Summer	road/pad	0.54	0.02	0.1	0.12	0.0001

[a]This value is average searcher efficiency multiplied by average carcass persistence probability. These values can be converted to the Ba and Bb parameters needed for EoA. See screenshots in Appendix B.

[b]The temporal risk fraction is the proportion of seasonal risk expected, based on the MSHCP all-bat arrival proportions and the number of turbines that pose risk to *Myotis* species in each season.

[c]These strata-specific g-values are the within-stratum detection probabilities multiplied by the product of the temporal risk fraction, the sampling fraction, and the area correction. For purposes of EoA analysis, we set DWP = temporal risk fraction × sampling fraction × area correction. Stratum-specific DWP values, based on the values in this table, are showin the EoA screenshots in Appendix B.

Table 14. Estimated detection probability (*g*) for Indiana bats and northern long-eared bats using Evidence of Absence with area correction data collected at the Headwaters Wind Farm, July 2 – October 15, 2019[1].

Season	Plot Type	Median *g*	Lower 90% CI	Upper 90% CI
Fall	Cleared	0.156	0.113	0.203
Fall	Soy	0.017	0.010	0.023
Fall	Road/Pad	0.04	0.025	0.06
Summer	Road/Pad	0.0001	0.00008	0.0002
Overall		**0.21**	**0.15**	**0.28**

[1]See screenshots in Appendix B showing the inputs for EoA based on these values.

Table 15. Variables used to estimate the detection probability (*g*) for Indiana bats and northern long-eared bats using Evidence of Absence framework*.

	Summer	Fall
Number of Searches	4**	10**
Search Interval	7 days	7 days
Full Plot Turbines Searched	0	40
Roads and Pad Turbines Searched	10	60
Probability of Detection - Cleared Plot	-	0.89
Probability of Detection - Road and Pad	0.85	0.85
Probability of Detection – Soy plot	-	0.55
Probability a Carcass was available for detection (rHat)	0.50	0.50
Area Correction – Cleared plot	-	0.80

Table 15. Variables used to estimate the detection probability (*g*) for Indiana bats and northern long-eared bats using Evidence of Absence framework*.

	Summer	Fall
Area Correction – Soy plot	-	0.80
Area Correction - Road Pad	0.12	0.12
k (as defined in HCP)	0.67	0.67

*Probability of detection, rHat, and area correction values are reported as median estimates from the fitted models. Calculation of *g* for EoA analysis was done such that variability in these values propogated to variability in *g*. Thus, inputting the values from this table into an EoA analysis will achieve very similar, though not exactly the same, results as presented in Tables 15, 16, and 17.

**Numbers of searches actually conducted were 5 for summer and 11 for fall. EoA functions assume an initial search at t = 0 such that inputting four searches restuls in 4 search days and, in turn, four search intervals.

Adaptive Management—EoA Short-Term Trigger

Mean annual take rate was estimated to be 7.33 (90% CI = 0.83 – 19.53) Indiana bats per year and 2.45 (90% CI = 0.01 – 9.45) northern long-eared bats per year (Table 16). The expected take rate was about 9.55 Indiana bats per year and 2.53 northern long-eared bats per year. The short-term trigger assesses the probability that the estimated take rate exceeds the expected take rate, $\Pr(\lambda > \tau)$. At a confidence level of $\alpha = 0.05$, $\Pr(\lambda > \tau)$ must be greater than or equal to 0.95 for the short-term trigger to fire. For Indiana bat, $\Pr(\lambda > \tau) = 0.27$ (Table 17). For northern long-eared bat, $\Pr(\lambda > \tau) = 0.31$ (Table 16). Neither probability meets or exceeds 0.95, indicating the short-term trigger was not been met and no adaptive management actions are necessary.

Adaptive Management—EoA Long-Term Trigger

Cumulative take to-date, M^* at $\alpha = 0.5$ (50th credible bound), is estimated to be 5 for Indiana bat and 1 for northern long-eared bat (Table 18). These values fall below the total permitted take for each species (258 Indiana bats and 136 northern long-eared bat over the 30 year permit term). The long-term trigger was not met and the project is in compliance for both species because $M^* < T$ for both species.Therefore, an avoidance response is not necessary.

Table 16. Estimated fatality rate (λ) using Evidence of Absence for studies conducted at the Headwaters Wind Farm from July 2 – October 15, 2019.

Species	Mean λ	90% CI
Indiana bat	7.34	0.83 – 19.53
Northern long-eared bat	2.45	0.01 – 9.45

Table 17. Probability that the estimated take rates exceeded the expected take rates of 9.55 Indiana bats per year and 2.53 northern long-eared bats per year. Probabilities were calculated using Evidence of Absence for studies conducted at Headwaters Wind Farm, July 2 – October 15, 2019.

Species	Expected Take Rate (τ)	$\Pr(\lambda > \tau)$*	Short-term trigger fires at $\alpha = 0.05$?
Indiana bat	9.55	0.27	No
Northern long-eared bat	2.53	0.31	No

Table 17. Probability that the estimated take rates exceeded the expected take rates of 9.55 Indiana bats per year and 2.53 northern long-eared bats per year. Probabilities were calculated using Evidence of Absence for studies conducted at Headwaters Wind Farm, July 2 – October 15, 2019.

* Pr($\lambda > \tau$) reads, "the probability that λ (the annual take rate) is greater than τ (the expected annual take rate based on the total permitted take, used as a threshold for adaptive management)." If this probability is less than 0.95 (e.g., α = 0.05 for a one-sided test), then no adaptive management is triggered because there is not sufficient evidence that the estimated annual take rate is greater than the expected annual take rate.

Table 18. Cumulative take estimate to date using Evidence of Absence for studies conducted at Headwaters Wind Farm, July 2 – October 15, 2019.

Species	Cumulative take (M*)	Permitted Take (T)	Long-term trigger fires at α = 0.05?
Indiana bat (50th credible bound)	5	258	No
northern long-eared bat (50th credible bound)	1	136	No

Proposed 2020 Search Methods

In 2020, HWF proposes to reach a g of 0.25 by searching all turbines as road and pads every two weeks through the fall (Table 19). In the summer, HWF proposes to search the 10 turbines with summer risk as 70-m cleared plots, every two days. In the fall, HWF proposes to search turbines once a week. Eleven turbines will be searched as cleared plots, 12 turbines will be searched as 70-m un-cleared plots, and the remainder will be searched as road and pad plots, out to 100 m.

Table 19. Proposed plot types, plot size, number of plots, and search frequency by season for 2020 post-construction monitoring at Headwaters Wind Farm in Randolph County, Indiana.

Season	Plot Type	Plot Size (m)	Number of Plots	Search Interval
Spring	Human Searches - Road and pad	100	100	14 days
Summer	Dog-handler Team –Clear Plots	70	10	2 days
Fall	Dog-handler Team – Un-cleared plots	70	12	7 days
	Dog-handler Team– Clear Plots	70	11	7 days
	Dog-handler Team -Road and pad	100	77	7 days

DISCUSSION

The monitoring completed during 2019 provided evidence that minimization measures implemented at the HWF reduced the take of Indiana bat and northern long-eared bats to a rate that is compatible with ITP compliance over the duration of the permit term. No adaptive management triggers were met for HWF in 2019.

HWF was the first project monitored under an ITP for Indiana bat and northern long-eared bat that used dogs to complete carcass searches. High rates of searcher efficiency were achieved through the use of dogs, in both cleared plots and standing soybeans. The results achieved at HWF are consistent with other researchers, which have measured searcher efficiency rates as high as 86% searcher efficiency in field conditions, depending on carcass size and vegetation cover (Arnett 2006; Reyes et al. 2016). These results provide additional support for the use of dogs as a method to increase detection probabilities in a manner that is cost effective both for direct costs and minimizing crop clearing costs, by including searches in areas such as standing soybean fields.

The detection probability was 0.21 with a 90% CI of 0.15 – 0.28 for the summer and fall monitoring period for 2019. The target value of g = 0.25 does fall within the 90% CI; however, the summer monitoring plan was designed to be implemented quickly and without considering a particular target detection probability, which resulted in a distribution of g that was skewed lower than desired. Summer monitoring in 2020 will be explicitly considered as a component of overall detection probability. Thus, the 2020 detection probability over all seasons is anticipated to continue meeting the target of g = 0.25, while shifting its overall distribution higher.

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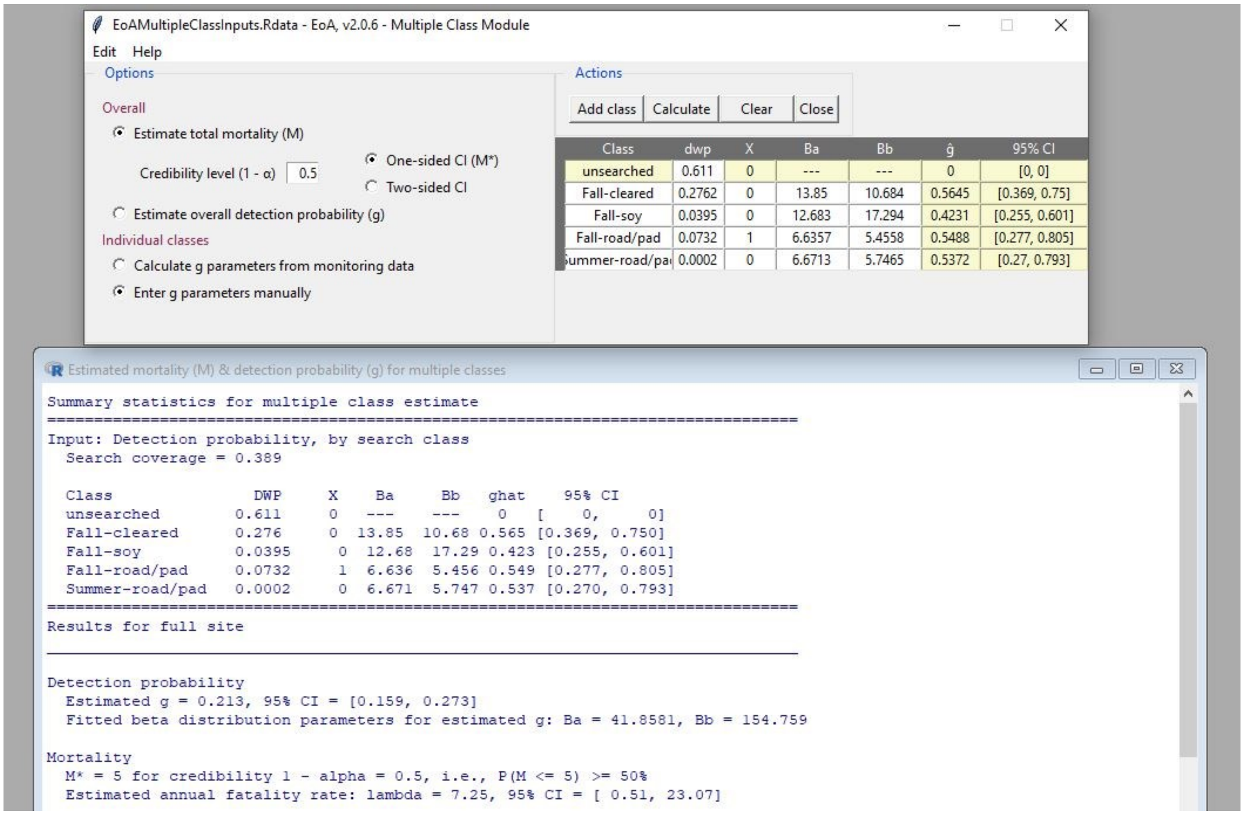
Appendix A. Gen-Est Estimates for 2019 Post-Construction Surveys at the Headwaters Wind Farm

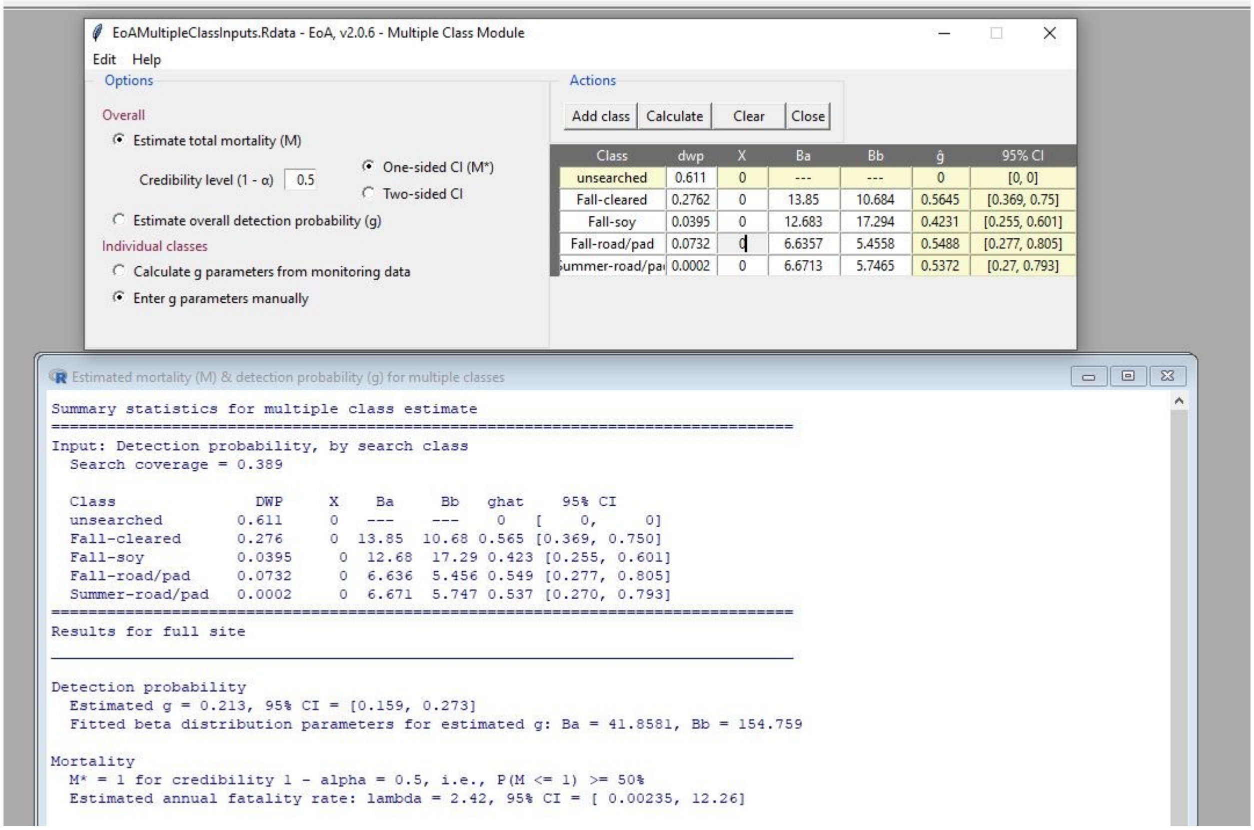
Appendix A1. Estimated fatality rates and adjustment factors for bats, with 90% confidence intervals, for all plots types for studies conducted at the Headwaters Wind Farm, Randolph County, Indiana, from July 2, 2019 to October 15, 2019.

Summer - weekly road/pad		Fall - weekly road/pad		Fall - weekly cleared plots		Fall - weekly soy plots		Fall - all plots	
10 turbines searched		60 turbines searched		35 turbines searched		5 turbines searched		100 turbines searched	
Estimate	90% CI	Estimate	90% CI	Estimate	90% CI	Estimate	90% CI	Estimate	90% CI
Probability of Available and Detected									
0.53	0.42 - 0.66	0.53	0.42 - 0.66	0.53	0.42 - 0.66	0.41	0.29 - 0.54		
Observed Fatality Rates (Fatalities/Turbine/Season(s))									
0.47	n/a*	1.12	1.12 - 1.12	8.48	8.48 - 8.48	2.59	2.59 - 2.59		
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s))									
6.23	n/a*	16.80	10.57 - 26.65	18.79	14.10 - 26.20	7.38	4.45 - 12.97	17.16	12.18 - 25.10
Adjusted Fatality Rates (Fatalities/MW/Seasons(s))									
3.11	n/a*	8.40	5.29 - 13.32	9.39	7.05 - 13.10	3.69	2.22 - 6.48	8.58	6.09 - 12.55
Searcher Efficiency									
0.85	0.73 - 0.92	0.85	0.73 - 0.92	0.89	0.70 - 0.96	0.55	0.37 - 0.72		
Area Adjustment									
0.12	0.08 - 0.17	0.12	0.08 - 0.17	0.80	0.67 - 0.95	0.80	0.67 - 0.95		
Carcass Persistence Probability (assuming 7-day search interval)									
0.61	0.49 - 0.73	0.61	0.49 - 0.73	0.61	0.49 - 0.73	0.61	0.49 - 0.73		

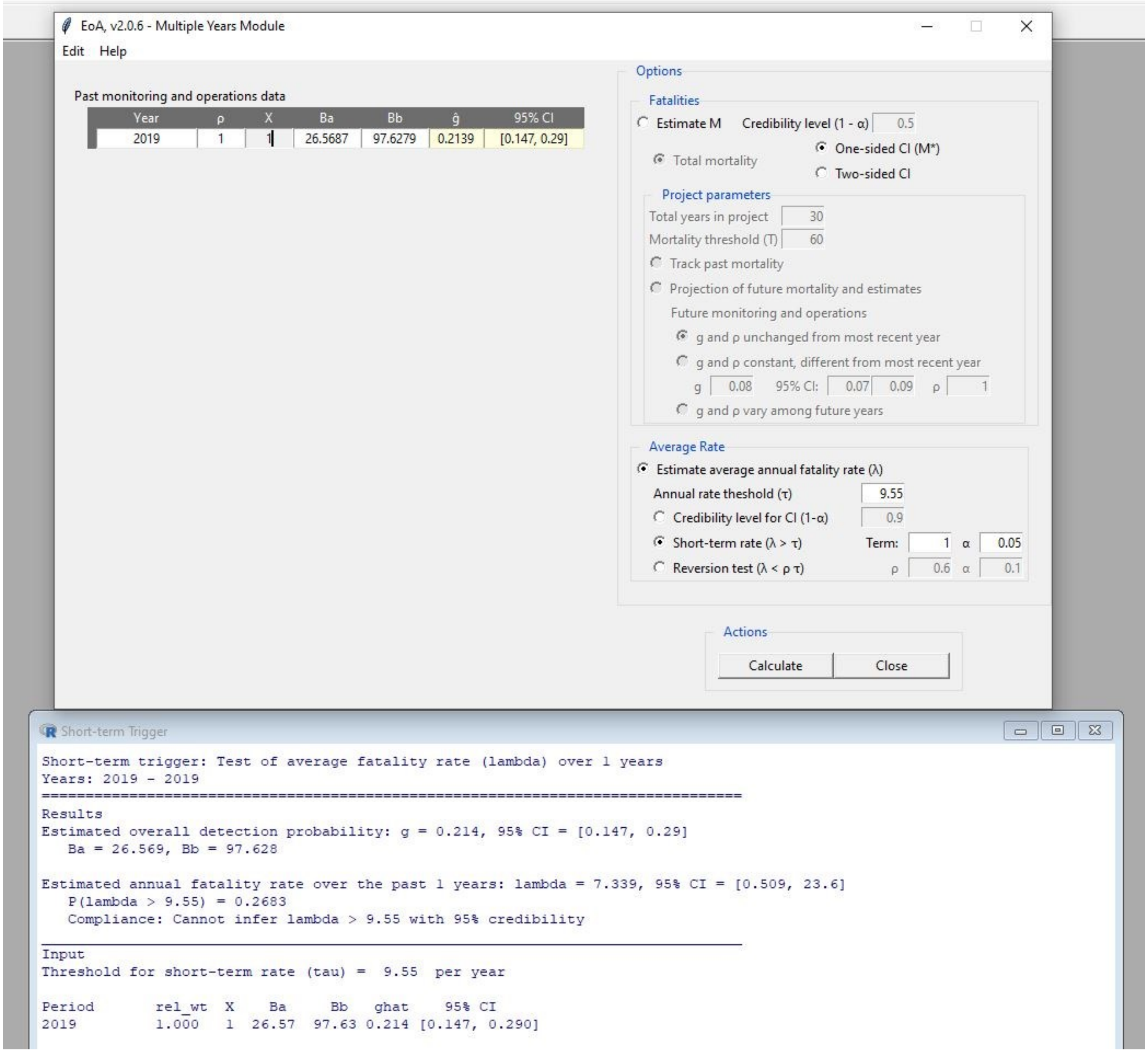
Appendix B. Additional information for the EoA analysis



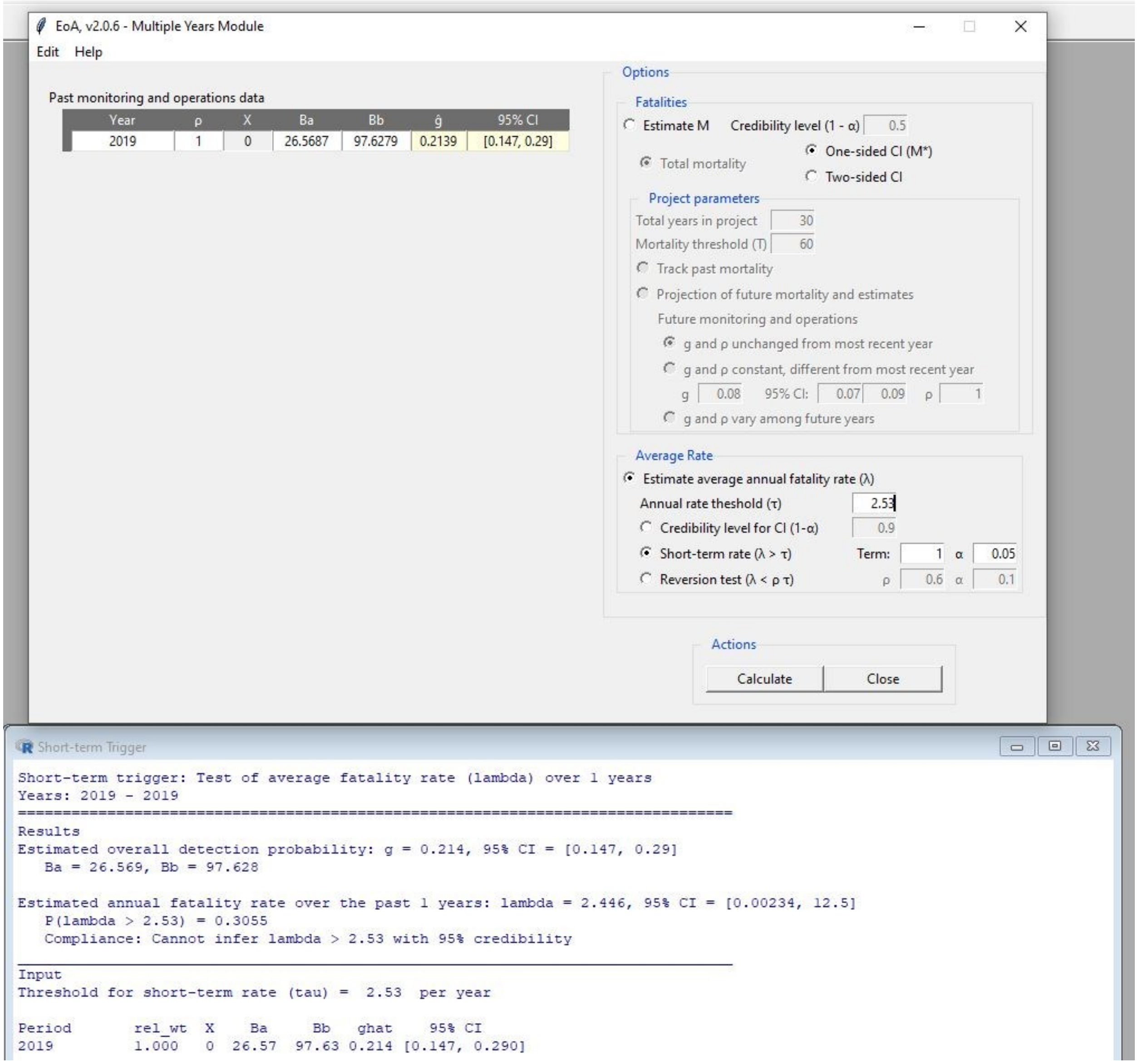
Appendix B1. Inputs and outputs from the EoA Graphical User Interface (GUI) Multiple Class Module for Indiana bat. Inputs are based on values reported in the main text. Note that estimates of overall detection probability from the EoA GUI will have smaller confidence intervals than those reported in the main text because the EoA GUI cannot propogate the uncertainty from DWP through to the final estimate.



Appendix B2. Inputs and outputs from the EoA Graphical User Interface (GUI) Multiple Class Module for northern long-eared bat. Inputs are based on values reported in the main text. Note that estimates of overall detection probability from the EoA GUI will have smaller confidence intervals than those reported in the main text because the EoA GUI cannot propogate the uncertainty from DWP through to the final estimate.



Appendix B3. Inputs and outputs from the EoA GUI Multiple Years module for Indiana bat.



Appendix B4. Inputs and outputs from the EoA GUI Multiple Years module for northern long-eared bat.