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

Year 4 Final Report

April 1 – July 31, 2022

Prepared for:

EDP Renewables

Attn: Erin O'Shea

1501 McKinney Street, Suite 1300
Houston, Texas 77010

Prepared by:

Aaron McAlexander, Ross Bailey, Anna Ciecka, Riley Knoedler, and Matthew Crane

Western EcoSystems Technology, Inc.
408 W. Sixth Street
Bloomington, Indiana 47404

January 18, 2023

EXECUTIVE SUMMARY

Headwaters Wind Farm, LLC (Headwaters) is operating the Headwaters Wind Farm (Project) in Randolph County, Indiana. This report details the post-construction monitoring studies conducted in 2022, consistent with the Project's Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP; TE85617C-0) for Indiana and northern long-eared bats (Covered Species). The Project obtained the ITP on June 4, 2019, and has since completed one fall season (2019) and two full-seasons (April 1 – October 15, 2020 and 2021) studies of monitoring. Monitoring was conducted in spring and summer of 2022 to complete the initial three full years of compliance monitoring. In 2022, turbines were operated with increased cut-in speeds during spring migration; turbines with designated summer risk per the Project's HCP were also operated with increased cut-in speeds during the summer.

Post-construction monitoring was completed in accordance with the study plan, which was approved by US Fish and Wildlife Service on February 23, 2022. The study plan was designed to achieve a 25% probability of detecting a single bat carcass (*g* of 0.25) for the 100 wind turbines at the Project. The overall goal of this post-construction fatality monitoring study was to generate reliable fatality estimates for the Covered Species and to evaluate compliance with the incidental take authorization granted under the Project's ITP. More specifically, the objectives of this study were to estimate take for the Covered Species using the Evidence of Absence (EoA) framework as outlined in the HCP and to determine if adaptive management was necessary to maintain compliance with the Project's ITP.

Standardized carcass searches for bat carcasses were completed at two plot types: full plots and road and pad plots, and were conducted by two types of searchers: technician and dog-handler team (consisting of one dog trained to detect carcasses and one handler). The frequency of searches varied across seasons, with more searches occurring when take of Covered Species was considered more likely to occur. Searcher efficiency and carcass persistence trials were also conducted during each season to correct for detection and scavenger bias.

No Covered Species were found at the Project. Sixty bats were found during the study. The most commonly found bat species were eastern red bat (46.7%), silver-haired bat (31.7%), hoary bat (11.7%), and big brown bat (10.0%). Species composition recorded at the Project was similar to previous studies at the Project and other wind facilities in Indiana. Fifteen bird carcasses were recorded; no federally or state-listed birds were found.

The *g* was 0.22 (90% confidence interval: 0.19-0.25). Based on data collected to date (2019, 2020, 2021 and 2022 studies), the EoA model estimated the mean annual fatality rates were 9.61 Indiana bats and 0.64 northern long-eared bats with an overall *g* of 0.26 (90% confidence interval: 0.24-0.28) throughout the initial three year monitoring period. The probability that the annual take rate exceeded the expected annual take rate was 0.46 for Indiana bat and 0.05 for northern long-eared bat. The cumulative take estimates through 2022 were 27 Indiana bat fatalities and zero northern long-eared bat fatalities. The estimated levels of Indiana bat and northern long-eared

bat take were below levels authorized within the ITP. No adaptive management actions are necessary at this time.

STUDY PARTICIPANTS

Aaron McAlexander	Project Manager and Permitted Bat Biologist
Quintana Hayden	Senior Reviewer
Anna Ciecka	Field Supervisor, Detection Dog Coordinator, Report Writer
Paul Rabie, Ph.D.	Senior Statistician
Riley Knoedler	Evidence of Absence Analyst
Matthew Crane	Statistician
Faith Kulzer	Lead Client Analyst
Kristen Klaphake	GIS Technician
Jeanette Haddock	Technical Editor
Ross Bailey	Field Technician, Crew Lead, Report Writer
Noelle Freeman & Raven	Dog-Handler & Detection Dog

REPORT REFERENCE

McAlexander, A., R. Bailey, A. Ciecka, Riley Knoedler, and Matthew Crane. 2023. Post-Construction Monitoring Studies for the Headwaters Wind Farm, Randolph County, Indiana, Year 4 Final Report: April 1 – July 31, 2022. Prepared for EDP Renewables (EDPR), Houston, Texas. Prepared by Western EcoSystems Technology, Inc., Bloomington, Indiana. January 18, 2023.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

INTRODUCTION 1

STUDY AREA 1

METHODS 4

- Standardized Carcass Searches 4
  - Number of Turbines Sampled, Search Frequency, and Plot Size 4
  - Search Methods 5
  - Data Collection 7
  - Carcass Identification and Agency Notification 8
- Bias Trials 9
  - Searcher Efficiency Trials 9
  - Carcass Persistence Trials 10
- Search Area Mapping 10
- Quality Assurance and Quality Control 10
- Statistical Analysis 10
  - Searcher Efficiency Estimation 11
  - Carcass Persistence Rate Estimation 11
  - Area Adjustment 11
  - Carcasses Excluded from Analysis 12
  - Covered Species Take and Detection Probability Estimates 12
  - Adaptive Management Triggers 13

RESULTS 14

- Standardized Carcass Searches 14
- Statistical Analysis 14
  - Bias Trials 14
  - Area Adjustment 15
  - Covered Species Take Estimates 16
  - Adaptive Management Triggers 17

CONCLUSIONS 19

REFERENCES 19

LIST OF TABLES

Table 1. Land cover types and percent composition at the Headwaters Wind Farm Permit Area, in Randolph County, Indiana. 2

Table 2. Seasonal curtailment regime at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 2

Table 3. Search effort by season and plot type at Headwaters Wind Farm in Randolph County, Indiana, from April 1 – July 31, 2022. 4

Table 4. Seasonal arrival proportions for the fall season at Headwaters Wind Farm in Randolph County, Indiana, from April 1 – July 31, 2022. 13

Table 5. Study period and overall probabilities of detection (g), Ba, and Bb and ρ for the Headwaters Wind Farm in Randolph County, Indiana, from 2019 – 2022. 17

Table 6. Probability the estimated take rates exceeded the expected take rates for studies conducted within the rolling average interval at the Headwaters Wind Farm, Randolph County, Indiana, ITP Years 1-4 (2019 – 2022). 18

Table 7. Cumulative take estimate to date using Evidence of Absence for studies conducted within the ITP term to date at Headwaters Wind Farm, Randolph County, Indiana, from ITP Years 1-4 (2019 – 2022). 19

LIST OF FIGURES

Figure 1. Turbine locations by search type and surrounding land cover at the Headwaters Wind Farm in Randolph County, Indiana. 3

Figure 2. Representative photo of conditions of a 100-meter road and pad plot at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 5

Figure 3. Representative photo of vegetation conditions in a 70-meter full plot at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 6

Figure 4. Dog-handler team Noelle Freeman (handler) and Raven (detection dog) performing a full plot search at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 7

Figure 5. The average probability of persistence, in days, at different search intervals at Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 15

Figure 6. Density of bat carcasses per area searched at road and pad plots and cleared plots at Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022. 16

Figure 7. Estimated annual take rate (λ) bats per year at Headwaters Wind Farm, Randolph County, Indiana, ITP Years 1-4 (2019 – 2022). 18

LIST OF APPENDICES

Appendix A. Carcasses found during the 2022 Post-Construction Monitoring Surveys

Appendix B. Searcher Efficiency and Carcass Persistence Model Fitting Results

Appendix C. Truncated Weighted Likelihood (TWL) Area Adjustment Model Fitting Results

Appendix D. Inputs for Single Class and Multiple Class Modules in Evidence of Absence

Appendix E. Screenshots of Inputs for Single Class and Multiple Class Modules in Evidence of Absence

INTRODUCTION

Headwaters Wind Farm, LLC (Headwaters), a subsidiary of EDP Renewables North America, LLC (EDPR), is operating the Headwaters Wind Farm (Project) in Randolph County, Indiana. EDPR obtained an Incidental Take Permit (ITP; TE85617C-0, dated June 4, 2019) for the federally listed endangered Indiana bat (*Myotis sodalis*) and endangered[1] northern long-eared bat (*M. septentrionalis*; hereafter Covered Species) from the US Fish and Wildlife Service (USFWS). The Project had completed one fall-only season (2019) and two full-seasons (April 1 – October 15, 2020 and 2021) of monitoring prior. Monitoring was conducted in spring and summer of 2022 to complete three full years of initial compliance monitoring. This report presents the results of the fourth consecutive survey period of compliance monitoring conducted under the ITP from April 1, 2022 to July 31, 2022. The objectives of this study were to estimate take of the Covered Species using the Evidence of Absence (EoA) framework as outlined in the Habitat Conservation Plan (HCP; Headwaters 2019) and determine if adaptive management is necessary to maintain compliance with the Project's ITP.

STUDY AREA

The primary land cover type within 100 meters (m; 328 feet [ft]) of the turbines (i.e., within the Permit Area) is cultivated crops, which covers 87.7% of the Permit Area (National Land Cover Database {NLCD] 2019). The next most common land cover is developed area (e.g., farmsteads) that composes approximately 5.5% of the site, followed by patches of deciduous forest composing 5.1% of the site and hay/pasture composing 1.1% (NLCD 2019). All other land cover types collectively make up less than one percent of the total land cover (Table 1, Figure 1; NLCD 2019).

The Project became fully operational in 2014, and consists of 100 2.0-megawatt (MW) Vestas V110 wind turbines that have a 95-meter (m; 311-ft) hub height and a 55-m (180-ft) blade length. All turbines are within the migratory range of the Covered Species, and EDPR adjusted turbine operations during the spring migration period to minimize impacts to the Covered Species. Additionally, EDPR adjusted turbine operations for 11 designated summer risk turbines during summer (Table 2).

[1] The northern long-eared bat was listed as threatened when the ITP was received. Its status will change to endangered as of January 30, 2023.

Table 1. Land cover types and percent composition at the Headwaters Wind Farm Permit Area, in Randolph County, Indiana.

Habitat	Acres	% Composition
Cultivated Crops	25,668	87.7
Developed[1]	1,602	5.5
Deciduous Forest	1,488	5.1
Hay/Pasture	320	1.1
Woody Wetlands	113	0.4
Herbaceous	55	0.2
Open Water	10	< 0.1
Emergent Herbaceous Wetlands	6	< 0.1
Mixed Forest	3	< 0.1
Evergreen Forest	2	< 0.1
Barren Land	1	< 0.1
Total[2]	**29,269**	**100**

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

[2] Sums may not equal total values shown due to rounding.

Data from National Land Cover Database. 2019

Table 2. Seasonal turbine operational regime at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Season	Turbines	Time of Day	Cut-In Speed	Feathering Below Cut-In[1]?	Temperature Threshold[2]
Spring (April 1 – May 15)	100 (All)	0.5 hour before sunset to 0.5 hour after sunrise	3.5 m/s	Yes	10 °C
Summer (May 16 – July 31)	89 turbines without summer risk	0.5 hour before sunset to 0.5 hour after sunrise	3.0 m/s	Yes	No
	11 turbines with summer risk	0.5 hour before sunset to 0.5 hour after sunrise	5.0 m/s	Yes	No

[1] Feathering means that turbine blades will be pitched into the wind such that they spin at less than one rotation per minute.

[2] Turbines will be feathered below cut-in when temperatures are above the threshold. In practice, the Project feathered on all nights regardless of temperature.

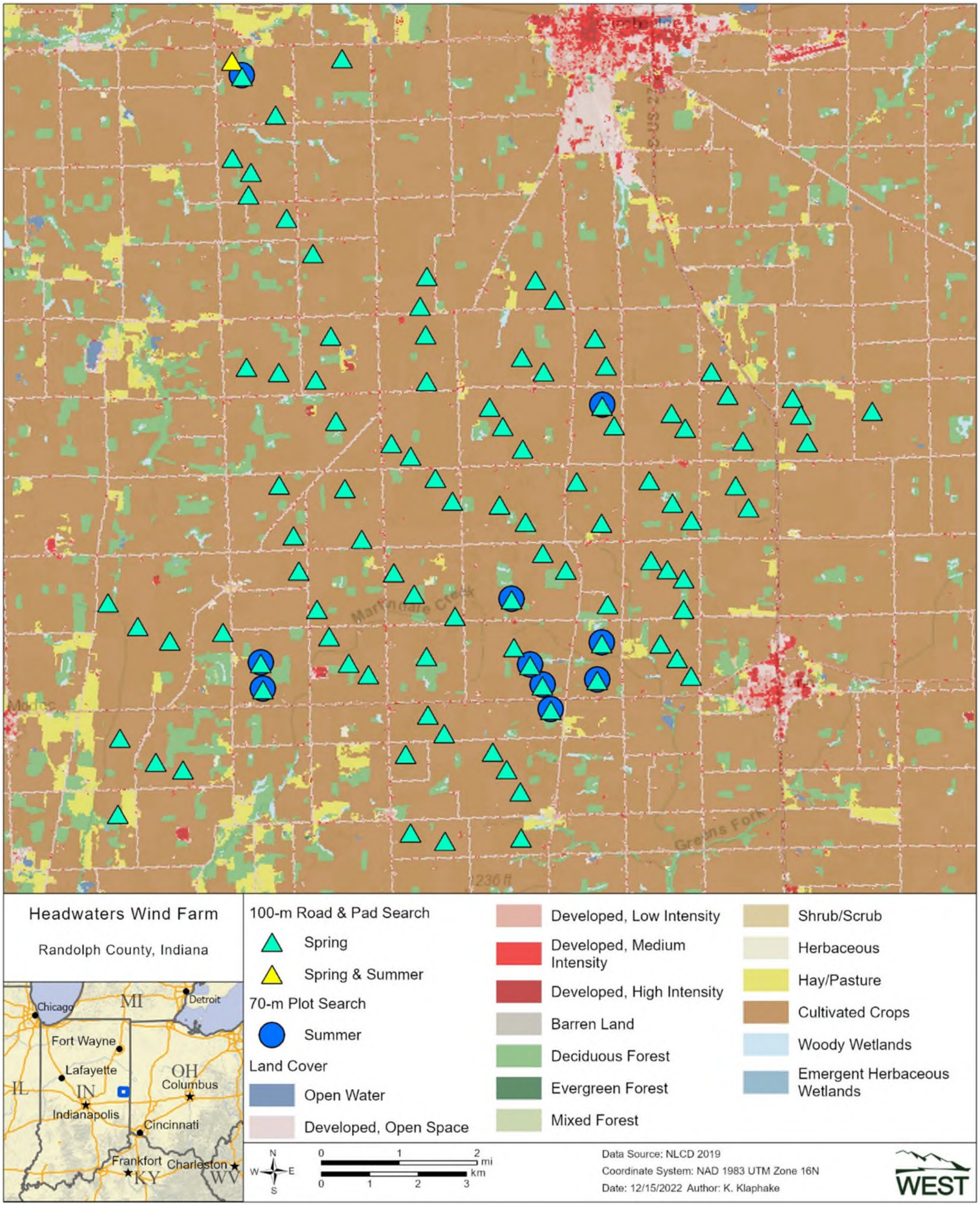


Figure 1. Turbine locations by search type and surrounding land cover at the Headwaters Wind Farm in Randolph County, Indiana.

METHODS

WEST used Project-specific data from previous post-construction monitoring studies at the Project (2019, 2020, and 2021 studies; see Rodriguez et al. 2020a, 2020b, and McAlexander et al. 2022) and other nearby EDP Renewables operated facilities, to develop a study plan that targeted a *g* of 0.25 to meet the monitoring commitments in the HCP (Headwaters 2019). WEST submitted a study plan to EDPR on January 28, 2022, and received approval from the USFWS on February 23, 2022 (M. Reed, USFWS, pers. comm.).

Standardized Carcass Searches

Number of Turbines Sampled, Search Frequency, and Plot Size

Technicians and dog-handler teams conducted standardized carcass searches (carcass searches) from April 1 – July 31, 2022. Search effort varied by season (Table 3), and was designed to maximize effort when the greatest number of Covered Species were expected to occur.

Table 3. Search effort by season and plot type at Headwaters Wind Farm in Randolph County, Indiana, from April 1 – July 31, 2022.

Season	Plot Type	Search Interval	Number of Turbines	Search Team
Spring (April 1–May 15)	100-m road and pad	14 days	100	Technician
Summer (May 16–July 31)	70-m full	3.5 days	10[1]	Dog-handler Team
	100-m road and pad	3.5 days	1	Technician

m=meter

[1] In 2021, turbine 48 had a summer season Indiana bat fatality. As a result, turbine 48 was reassigned as a summer risk turbine by USFWS and was included as a full plot for the 2022 summer season.

A technician searched the gravel road and pad areas (road and pad plots) under all 100 turbines to a distance of 100 m (328 ft) from the turbine every other week during the spring (Table 3, Figure 2). During the summer, summer risk turbines were searched on a twice-weekly interval. A dog-handler team searched 10 turbines as full plots within a 70-m (230-ft) radius and a technician searched one road and pad plot to a distance of 100 m from the turbine twice a week during the summer (Table 3, Figure 3).

The full plot types for the summer period were originally planned to be a mix of six cleared plots, with the entire search area mowed within 10 to 15 centimeters (four to six inches) in height, and four uncleared plots, with transects mowed in a cross pattern, approximately 1.5 m (4.9 ft) wide, to assist dog teams with plot access but reduce overall crop damages. However, due to dry conditions resulting in poor crop growth, uncleared plots did not require mowing until the final week of surveys, in which three transect lanes were mowed in the soybean (*Glycine max*) crop to assist with plot access. Since plot conditions were consistent throughout a majority of the survey season, analysis did not distinguish between cleared and uncleared plot types. Therefore, this report refers only to full plots.

Figure 2. Representative photo of conditions of a 100-meter road and pad plot at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Search Methods

WEST used two types of search methods: a technician, or human only visual search, and a dog-handler team or olfactory search, where the team consisted of one technician/handler and one trained detection dog. All personnel followed the Project's study plan, including proper handling and reporting of carcasses. Carcass searches were conducted during the day, beginning as early as first light.

Road and Pad Searches — Technician

Technicians walked transects spaced five m (16 ft) apart at a rate of approximately 45–60 meters per minute (m/min; 148–197 ft/min) on all gravel road and pad areas within 100 m of the turbine. The technicians scanned the area for carcasses on both sides of the transects out to approximately 2.5 m (8.2 ft) to ensure full visual coverage of each search area. Technician searches were only conducted on road and pad plots.

Figure 3. Representative photo of vegetation conditions in a 70-meter full plot at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Plot Searches — Dog-handler Team

Dog-handler teams searched 70-m full plots for bat carcasses (Figure 4). Prior to each search, handlers determined the survey start point 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 the detection dog to start searches perpendicular to the wind to maximize scent detection. Both wind speed and crop density can affect dispersal of the target odor (i.e., bat carcasses) across the search area. To maximize detection rates during an olfactory search, transect width varied with vegetation density, ranging from five to 10 m (16 to 33 ft) apart in densely vegetated areas, to 10–15 m (33–49-ft) in shorter vegetation. Detection dogs were rewarded with either a food reward or a short play session when they correctly alerted to a bat or bird carcass.

Figure 4. Dog-handler team Noelle Freeman (handler) and Raven (detection dog) performing a full plot search at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Dog-Handler Team Evaluation

Detection dogs were considered candidates for carcass searches if they met basic temperament and obedience criteria, and demonstrated the trainability to detect bat and/or bird carcasses. Temperament characteristics sought after were high-energy, and a high food or toy drive. Prior to conducting searches at the Project, handlers trained their detection dogs on the scent of bat carcasses following methods derived from search and rescue programs and drug detection (Kay 2012, Helfers 2017). Dogs were initially trained with either cotton scent swabs that had been rubbed on bat carcasses, progressing to dehydrated bats, or directly with dehydrated bat carcasses, at increasing distances over a period of three to four weeks. Once the dog achieved a passing grade of 80% or higher in a scent recognition test, consisting of ten blind trial lineups using dehydrated bats, the dog and handler were evaluated in the field to measure their performance. The detection dog coordinator conducted a two day field evaluation of each dog-handler team; after teams achieved a searcher efficiency of 75% or greater for 15–30 dehydrated bats placed during blind evaluation trials, the teams were approved to conduct standardized carcass searches. Because the objective of the study focused on detecting bat carcasses, dogs were not explicitly trained on native bird carcasses; however, all detection dogs alerted on bird carcasses in the field, and handlers rewarded bird finds in the field to encourage future alerts to bird carcasses. A border collie breed was used at the Project as the primary detection dog.

Data Collection

Technicians recorded the date, start and end times, technician name, turbine number, type of search and if any carcasses were found for each scheduled search. When a carcass was found, technicians placed a flag near it and continued the search. After searching the entire plot, the technician returned to record information for each carcass on a carcass information 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 using Geographic Coordinate System (latitude and longitude), habitat surrounding carcass, carcass condition (e.g., intact, scavenged, dismembered), and estimated time of death (e.g., less than one day, two days).

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—a carcass 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.

Technicians took digital photographs of each carcass, including any visible injuries, and surrounding habitat. No bird carcasses were collected, but a marker was placed next to each bird carcass to avoid duplicate counting. Bat carcasses were collected under the Project's ITP (TE85617C-0), WEST's Federal Native Endangered and Threatened Species Recovery Permit (TE234121-9), and WEST's State Scientific Collection Permit (2229). Technicians placed each bat carcass in a re-sealable plastic bag labeled with a unique carcass identification number, turbine number, and date, for storage in a freezer on site. Leather gloves covered by nitrile or latex gloves were used to handle all bat carcasses to eliminate possible transmission of rabies or other zoonotic diseases, and to reduce possible human scent bias on any carcasses used later in bias trials. Live, injured bats were recorded and considered fatalities for analysis purposes when observed in search areas, and were handled in accordance with permit conditions (left in place).

Carcasses found in non-search areas (e.g., outside of a plot boundary) or outside of the scheduled study period, were recorded as incidental discoveries and documented following the same protocol for those found during standard searches, but were not included in analysis.

Carcass Identification and Agency Notification

Identification of bird carcasses was verified by biologists with significant field experience in identification of birds and their feathers. A federally permitted bat biologist (TE33467D-0) identified all bat carcasses via photographs throughout the survey period, or in hand at the end of the surveys. The USFWS and the Indiana Department of Natural Resources (IDNR) would have been notified within 24 hours of the positive identification of any state- or federally listed species, but none were identified during the searches.

Tissue samples were collected from heavily scavenged or decomposed carcasses that could not be positively identified and had potential to be a Covered Species. Tissue samples were submitted to a USFWS-approved laboratory, the East Stroudsburg University Wildlife Genetics Institute for identification. Bat carcasses that were heavily scavenged but did not have potential to be a Covered Species (i.e., fur was present on the wing, or the forearms measured more than 42 millimeters [1.6 inch] long) were identified to the closest genus or group possible and were not sent off for further identification. Bat carcasses, or representative hair/tissue samples from individual carcasses, are to be delivered to USFWS by January 31, 2023.

Bias Trials

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the probability that a carcass was found by searchers. Searcher efficiency trials were conducted in the same areas where carcass searches occurred. Technicians conducting carcass surveys did not know when searcher efficiency trials were being conducted or the location of the trial carcasses. Trial carcasses consisted of eastern red bats (*Lasiurus borealis*), silver-haired bats (*Lasionycteris noctivagans*), and big brown bats (*Eptesicus fuscus*) that had previously been found on site or provided by Indiana State University. Sixty-seven carcasses were placed across all seasons and plot types to account for differences in search conditions due to vegetation, topography, or weather.

Multiple trials were conducted in each season to measure potential changes in plot conditions on searcher efficiency over time. Each trial carcass was discreetly marked with a black zip-tie and/or a piece of electrical tape around the upper forelimb for identification as a study carcass. Carcasses were dropped from waist-height or higher and allowed to land in a random posture. The trial administrator walked in a meandering path and dropped trial carcasses for detection dogs the day prior to the next search to allow time for the scent to pool and disperse, and to eliminate a direct scent trail. For technician search trials, the trial administrator placed carcasses prior to the technician searching the plot, either the night before or the morning of searches depending on work schedules.

Searchers had one chance to locate trial carcasses during the first search after carcass placement. 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. Following searches, any carcasses that were not detected were checked to confirm availability. Forty-five trial carcasses were left in place and used for carcass persistence trials.

Carcass Persistence Trials

The objective of carcass persistence trials was to estimate the average probability a carcass would persist, or be available for detection in the field, given the search interval. Carcasses could be removed by scavenging or rendered undetectable by typical farming activities. A minimum of 15 trial carcasses were placed in each season and plot type to incorporate the effects of varying weather and scavenger densities on carcass persistence. No more than two trial carcasses were placed in a plot to avoid potential over-seeding and attracting scavengers.

Technicians 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 four days, then on day 7, 10, 14, 20, and 30. Trial carcasses were monitored until they were completely removed or the trial period ended. Dog-handler teams were used on the 70-m full plots to determine when carcasses were removed, while technicians determined the status of carcasses placed on 100-m roads and pad plots.

Search Area Mapping

Plot boundaries were used to verify if carcasses were found inside the search areas, and to inform the distribution of carcasses around turbines to estimate the number of carcasses that fell inside or outside of search areas. Full plots and road and pad plots were delineated in prior survey years using a 72-m radius GIS projection and Eos sub-meter global positioning satellite unit to designate non-searchable areas within the plots. An additional 2.0 m (6.6 ft) were added to the radius of the plots to account for the width of the turbine tower.

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 and measures were implemented. A Microsoft® SQL Server database was developed to store, organize, and retrieve survey data. All data forms and electronic data files were retained for reference.

Statistical Analysis

The Evidence of Absence (EoA; Dalthorp et al. 2017) modeling framework was used to estimate take of Covered Species. EoA was used with data collected in the field to estimate the overall probability of detecting a bat carcass, the take rate of Covered Species, and the number of Covered Species fatalities that occurred. Data used in the EoA model included number of Covered Species fatalities, fatality spatial data from all bats found during surveys, the results of searcher efficiency and carcass persistence trials, the seasonal arrival distribution of bats (described below), and the detection reduction factor (k; described below).

Searcher Efficiency Estimation

Searcher efficiency was estimated separately for technicians and dog-handler teams to account for different modes of detection (i.e., technicians use sight, whereas dogs use scent). EoA uses raw searcher efficiency data (e.g. number of found and available trial carcasses) to inform overall probability of detection. However, to determine if searcher efficiency data should be pooled, or separated by strata such as season and/or plot type, searcher efficiency was modeled using logistic regression. For both technicians and dog-handler team models, model selection was completed using an information theoretic approach known as AICc, or corrected Akaike Information Criterion (Burnham and Anderson 2002). The best model was selected as the most parsimonious model within two AICc units of the model with the lowest AICc value. Searcher efficiency data were input into the EoA software according to the model selection results.

The change in searcher efficiency between successive searches was defined by a parameter called the detection reduction factor (*k*) that can range from zero to one. When k is zero, it implies a carcass missed on the first search would never be found on subsequent searches. A *k* of one implies searcher efficiency remains constant no matter how many times a carcass was missed. Huso et al. (2017) estimated a value of *k* = 0.67 for bats, and this value was used to calculate bat fatality estimates using EoA, per the HCP.

Carcass Persistence Rate Estimation

Data collected during carcass persistence trials were used to estimate the probability carcasses remained available to be located by the searcher, given the search interval (i.e., the time between scheduled searches). The average probability a carcass persisted was estimated using an interval-censored survival regression with four potential distributions: exponential, log-logistic, lognormal, and Weibull distributions (Kalbfleisch and Prentice 2002, Dalthorp et al. 2018). Season and plot type were used as potential covariates. The best model was selected as the most parsimonious model within two AICc units of the model with the lowest AICc value. The parameter estimates of the selected model (α [shape] and β [scale], including the 95% CI of β) were used as inputs in the EoA Single Class module.

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 proportion of searched 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 using site-specific fatality locations. The TWL approach uses weights based on probability of detection and the proportion of area searched in each 1.0-m annulus around the turbine. Distributions considered were normal, gamma, Gompertz, Rayleigh and Weibull (parameterized according to R Development Core Team [2016] and Yee [2015]). The best model was selected using AICc. 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 Analysis

Carcasses were excluded from analysis when the carcass 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 TWL fitting procedure accounts for unsearched areas. Carcasses found prior to the start of surveys (e.g., a carcass found on a plot in the spring that was estimated to have died prior to April 1) were also excluded because the carcass occurred outside of the study period. Note that carcasses found in a plot incidentally (e.g. found by maintenance personnel) were included in the analysis if that plot had a scheduled search in the future. If a carcass of a Covered Species had been found outside of the spatial or temporal scope of the survey design it would still be excluded from the area correction estimate, but would be included in the EoA fatality estimate following Dalthorp et al. 2020.

Covered Species Take and Detection Probability Estimates

EoA was used to estimate the detection probability (g) median cumulative take to-date (M^*), mean annual take rate (λ), and evaluate the probability that the estimated take rate (λ) exceeded the expected take rate (τ) for Indiana bat and northern long-eared bat (i.e., Covered Species). Estimates were calculated using the EoA method (Dalthorp et al. 2017), using the Single Class, Multiple Class, and Multiple Years modules of EoA.

The EoA Single Class module is used to estimate the detection probability for each independent search stratum (e.g. season by plot type combination). This resulted in alpha (α) and beta (β) parameters that defined the beta distribution of detection probability in each stratum. The EoA Multiple Class module was then used to combine detection probability distributions across strata (i.e, 70-m full plots, and road and pad plots), with weights for each class (density-weighted proportion, or "DWP" in the software) defined by the within-season sampling fraction, relative turbine operations, and seasonal risk. The Multiple Class module of EoA requires weights (DWP) to sum to 1.0 (representing 100% of the risk to bats). When this module is used, unsearched strata are represented with near-zero detection probabilities and beta distribution parameters are set to Ba = 0.01 and Bb = 1,000 (a detection probability of 10^{-5}) for unsearched areas within each stratum. The results from the Multiple Years module (Ba and Bb parameters for the detection probability for the permit term to date) were used to estimate M^* (the median cumulative take over the life of the permit), λ (the underlying annual take rate across the single monitoring period) and its 95% CI, and the probability that $\lambda > \tau$, where τ is the authorized take number divided by the number of years in the permit. Appendix E shows how the compliance metrics were calculated using the EoA Graphical User Interface[2]. For this study, cross-season relative turbine operations were calculated as the number of visits in each season, during which turbines were operating, divided by the total number of visits in each season. Values were re-scaled to sum to one across the three seasons. Weights for spring, summer, and fall were based on the carcass arrival proportions from the Midwest Wind Energy Multi-Species HCP (USFWS 2016): 0.07% in spring, 36% in summer, and 57% in fall. However, the present analysis only covered a portion of the spring season. Consequently, spring and summer arrival proportions were rescaled to 0.16 and

[2] There may be minor differences between screen shots and the results in the main text because EoA is a stochastic estimator, leading to slightly different estimates each time the modules are run.

0.84 because the Year 4 study was conducted to complete the initial three-year HCP monitoring requirement (which began with a partial summer and fall Year 1 study), and thus fall was not included in the 2022 estimate. The summer risk estimate was multiplied by 0.11 to reflect relatively fewer risk turbines during summer, and the seasonal weights were again rescaled to sum to 1.0 for spring and summer (Table 4). These values defined the weights for combing the Beta distribution parameters across seasons.

Furthermore, the Multiple Years Module was used to estimate the site-wide, cumulative detection probability for 2022. The EoA Multiple Years Module requires the input ρ, which weights the years appropriately for combining Beta distribution parameters. In this module, the weights (ρ in the software) need not sum to 1.0, and a weight of 1.0 is assumed to represent a typical risk year. Weights may be more or less than 1.0 based on turbine operations that differ between years. The 2022 detection probability was combined with the 2019 – 2021 detection probabilities using the multiple years module. The EoA Multiple Years module requires the input ρ, which weights the years appropriately. Annual weights for 2019 -2021 are described in Rodriguez et al. 2020a, 2020b and McAlexander et al. 2022. The value for ρ was set to 0.88 for 2019 because the ITP was issued part way through summer, meaning about 88% of total annual risk was realized in 2019. In 2020, the Project was fully operational for all three seasons, so ρ was set to 1. In 2021, there were comparatively long periods of turbine down-time across the facility, and as described in that year's report, ρ was set to 0.91. The value for ρ in 2022 was 0.16 because only spring and summer seasons were studied (Appendix D4).

Table 4. Seasonal arrival proportions for the fall season at Headwaters Wind Farm in Randolph County, Indiana, from April 1 – July 31, 2022.

Season	Seasonal Arrival Proportion	Cross-season Relative Operation	Re-Scaled Season Weights
Spring (April 1 – May 15)	0.16	1	0.64
Summer (May 16 – July 31)	0.84	.11	0.36

The results from the Multiple Years module (Ba and Bb parameters for the detection probability for the permit term to date) were used to estimate *M** (the median cumulative take over the life of the permit), λ (the underlying annual take rate over the past four monitoring periods) and its 90% CI, and the probability that $\lambda > \tau$, where τ is the authorized take number divided by the number of years in the permit. Appendix D shows how the compliance metrics were calculated using the EoA Graphical User Interface.

Adaptive Management Triggers

The estimates from the EoA analysis were used to test two adaptive management triggers: a short-term test of whether the estimated take rate exceeded 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 each of the Covered Species.

Evidence of Absence Short-term Trigger

The EoA short-term trigger was 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 was designed to determine if an adaptive management response was needed to prevent the cumulative take estimate from actuating a response to the long-term trigger test. The short-term trigger tests if the estimated annual take rate (λ) exceeded the expected take rate (τ = T ÷ years in permit) at a confidence level of α = 0.05, per the HCP. The Project short-term trigger was designed to evaluate a rolling window of six years of post-construction monitoring data. If, within any 6-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 median cumulative take estimate (M*) remains within the permitted limit over the ITP term. Four survey periods of data were used in this analysis, 2019 – 2022.

<u>Evidence of Absence Long-term Trigger</u>

The EoA long-term trigger was designed to test if the cumulative take to date was equal to or greater than the permitted take (T). Per the HCP, cumulative take to date (*M**) was estimated at a confidence level of α = 0.5 (using the median, or 50^{th} credible bound, of the posterior distribution of estimated mortality). If the cumulative take to date at α = 0.5 was less than or equal to the total permitted take (*M** ≤ T), then no changes are necessary. If the cumulative take to date at α = 0.5 was greater than the total permitted take (*M** > T) then the take limit was met and the Project must enact avoidance measures.

RESULTS

Standardized Carcass Searches

Five hundred twenty-six searches were conducted during the spring and summer monitoring seasons; 13 searches (less than 3%) were missed due to turbine maintenance, weather constraints, and/or safety hazards.

No federally or state-listed bat or bird species were found. Sixty bat carcasses and 15 bird carcasses were found during standardized searches and incidentally (Appendix A). The most commonly found bat species were eastern red bat (28 carcasses; 46.67%) and silver-haired bat (19 carcasses; 31.7%), followed by hoary bat (*Aestus cinereus*; seven carcasses; 11.7%) and big brown bat (six carcasses; 10.0%).

Statistical Analysis

Bias Trials

<u>Searcher Efficiency Trials</u>

Sixty-seven bats were placed for searcher efficiency trials on eleven separate dates, of which 53 remained available for search teams to find across all plot types. Because dog-handler teams only searched full plots in the summer season, and all full plots were considered a single stratum, there were no covariates to model. The best-fit model for searcher efficiency on road and pad plots did not support the inclusion of season as a covariate, meaning there was not a statistically meaningful difference between searcher efficiency rates across seasons (Appendix B1, B2). Searcher efficiency rates ranged from 81% on road and pad plots to 84% on full plots.

Carcass Persistence Trials

Forty-five carcasses were placed to estimate carcass persistence. The best-fit model for carcass persistence rates was a lognormal distribution with no covariates. Carcass persistence did not vary by season or plot type (Appendix B3, B4). The average probability that a carcass persisted through a 14-day search interval was 0.49 (90% CI: 0.39-0.59) for road and pad plots in spring (Figure 5). The probability of a carcass persisting through a 3.5-day search interval was 0.68 (90% CI: 0.57-0.78) on road and pad plots and full plots in summer (Figure 5).

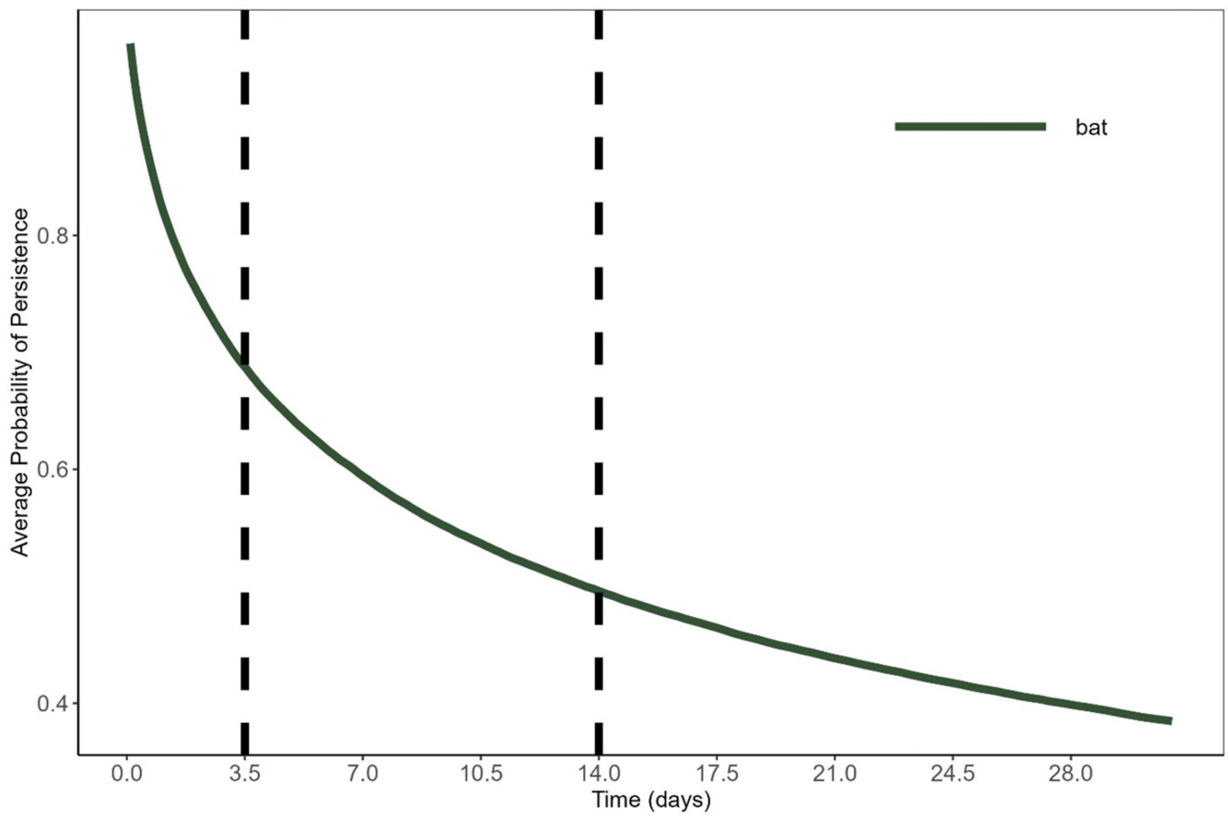


Figure 5. The average probability of persistence, in days, at different search intervals at Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Area Adjustment

Nine of the 60 bats found during the monitoring season were excluded from modeling the area adjustment for EoA. Four bat carcasses were excluded from analysis because they were found off plot. Another five bats were excluded because their estimated time of death was prior to the start of surveys (Appendix C1).

The best-fit model for the carcass-density distribution of bats (Figure 6) with respect to distance from turbine base was a Weibull model (Appendix C2). Area adjustments were calculated separately for bats on the 100-m road and pad plots and 70-m full plots. Carcass counts in the spring were not large enough to model carcass distributions separately by season and were pooled across seasons to inform one overall carcass-density distribution. The area adjustment for bats at 100-m road and pad plots was 0.09 in spring and 0.07 for summer; the area adjustment for bats at 70-m full plots was 0.96 (Appendix C3).

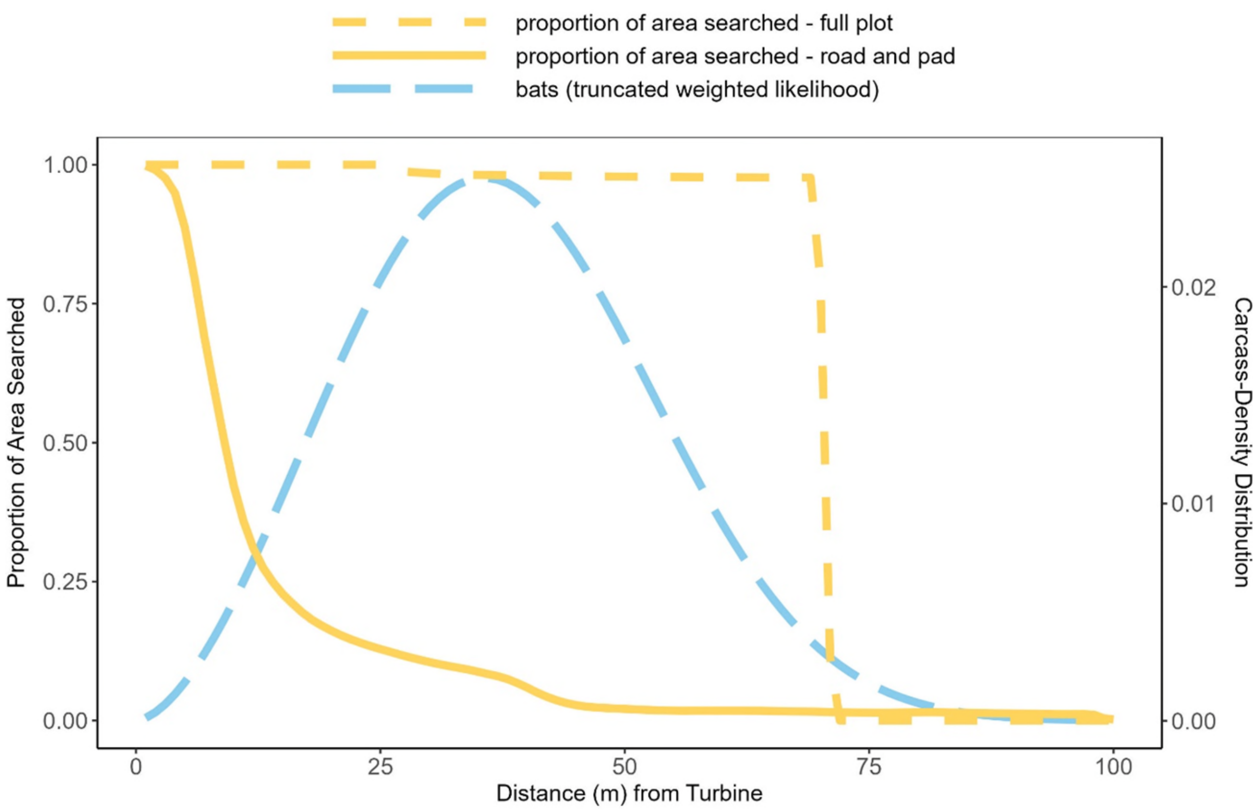


Figure 6. Density of bat carcasses per area searched at road and pad plots and full plots at Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Covered Species Take Estimates

No Covered Species carcasses were found during the 2022 study. To date, seven Indiana bats and zero northern long-eared bats have been found under the ITP. The probability of detection distribution (*g*) achieved for the 2022 monitoring period had a mean of 0.22 (90% CI: 0.19–0.25; Table 5). Inputs required to run the EoA Single Class module and stratum-specific *g* distribution values and inputs required for the Multiple Class module are described in Appendix D with representative inputs into EoA Software v2.0.7 provided in Appendix E.

Table 5. Study period and overall probabilities of detection (g), Ba, and Bb and ρ for the Headwaters Wind Farm in Randolph County, Indiana, from 2019 – 2022.

Year	Ba[1]	Bb[1]	*P*[2]	*g*	90% CI[3]
2019 (fall only)	26.57	97.63	0.88	0.21	0.16-0.28
2020	522.96	1728.37	1	0.23	0.22-0.25
2021	304.41	576.54	0.91	0.34	0.32-0.37
2022 (spring + summer)	98.54	348.59	0.16	0.22	0.19-0.25
Short-Term Trigger (Based on total 3 Year monitoring requirements))	326.09	923.17	NA	0.26	0.24-0.28
Long-Term Trigger (Cumulative)	326.09	923.17	NA	0.26	0.24-0.28

[1] Ba and Bb are the parameters for the Beta distribution used to characterize the probability of detection. The *g* value is the mean of that distribution.

[2] ρ is the weight in the weighted average that was used to combine the probability of detection distributions across years.

[3] CI = confidence interval

Mean annual take rates based on the complete initial three years of HCP-required monitoring (2019–2022) were estimated to be 9.61 (90% CI: 4.63-16.09) Indiana bats per year and 0.64 (90% CI: 0.00 – 2.46) northern long-eared bats per year (Table 6). The expected average annual take rates reported in the HCP were 9.55 Indiana bats per year and 2.53 northern long-eared bats per year (Headwaters 2019).

Cumulative take under the ITP to-date (2019–2022), *M*,* at $\alpha = 0.5$ (50th credible bound), was estimated to be 27 Indiana bats and zero northern long-eared bats (Table 7). The total take permitted by the ITP is 258 Indiana bats and 68 northern long-eared bats over the 27-year permit term (Table 7; Headwaters 2019).

Adaptive Management Triggers

<u>Evidence of Absence Short-term Trigger</u>

The short-term trigger assesses the probability that the estimated take rate exceeded the expected take rate, $Pr(\lambda > \tau)$. At a 95% confidence level ($\alpha = 0.05$), $Pr(\lambda > \tau)$ must be greater than or equal to 0.95 for the short-term trigger to fire. For Indiana bat, $Pr(\lambda > \tau) = 0.46$ and northern long-eared bat, $Pr(\lambda > \tau) = 0.05$ (Table 6). Neither probability meets or exceeds 0.95, indicating the short-term trigger was not met and no adaptive management actions are necessary (Table 6; Figure 7; Headwaters 2019).

Table 6. Probability the estimated take rates exceeded the expected take rates for studies conducted within the rolling average interval at the Headwaters Wind Farm, Randolph County, Indiana, ITP Years 1-4 (2019 – 2022).

Species	Mean λ (90% CI)	Expected Take Rate (τ)	Pr(λ > τ)[1]	Short-Term Trigger Fires at α = 0.05?
Indiana bat	9.61 (4.63-16.09)	9.55	0.46	No
Northern long-eared bat	0.64 (0.00–2.46)	2.53	0.05	No

[1] Pr(λ > τ) 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 was less than 0.95 (e.g., α = 0.05 for a 1-sided test), then no adaptive management was triggered because there was not sufficient evidence that the estimated annual take rate was greater than the expected annual take rate.

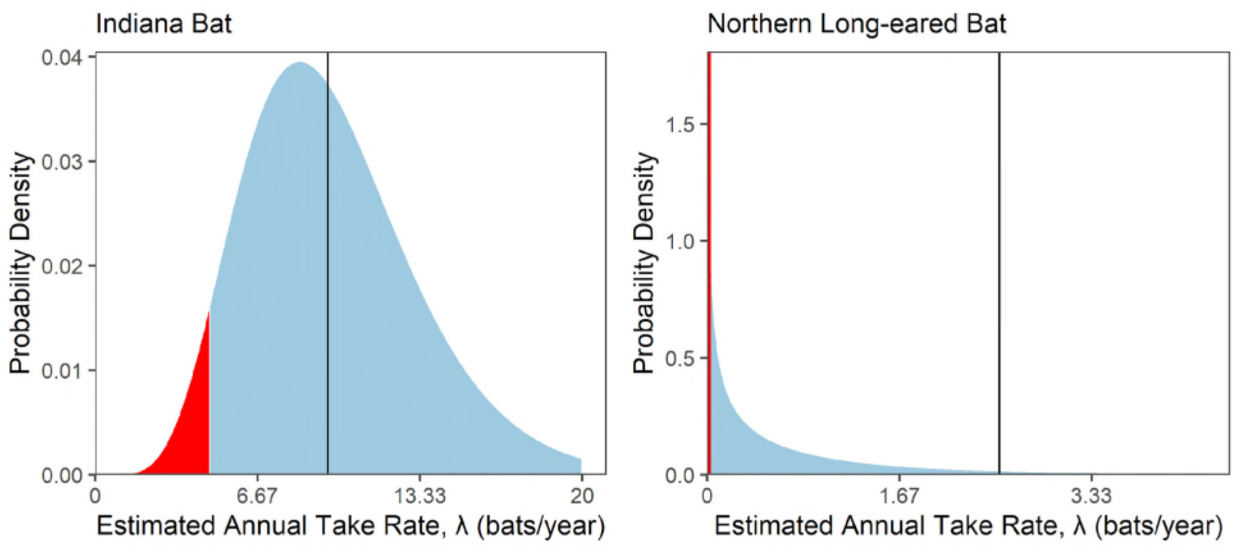


Figure 7. Estimated annual take rate (λ) bats per year at Headwaters Wind Farm, Randolph County, Indiana, ITP Years 1-4 (2019 – 2022).

Note: The red region of the posterior distributions shows the region of the lower 5% quantile of the distributions (red region may not be visible when the posterior distribution is skewed heavily toward zero). The vertical line marks the expected take rate. The short-term trigger evaluates whether the vertical line falls within or to the left of the red region of the posterior distributions. For both species, the short-term trigger was not met because the vertical line (expected take rate) was not within or to the left of the red regions. In other words, the probability that estimated take rate was greater than the expected take rate does not exceed 95%.

Evidence of Absence Long-term Trigger

The estimated cumulative take to date, M^* at α = 0.5 (50th credible bound), was below the total permitted take for both Covered Species (Table 7). 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 7. Cumulative take estimate to date using Evidence of Absence for studies conducted within the ITP term to date at Headwaters Wind Farm, Randolph County, Indiana, from ITP Years 1-4 (2019 – 2022).

Species	Cumulative take (M*)	Permitted take (T)	Long-term trigger fires at α = 0.5?
Indiana bat (50th credible bound)	27	258	No
northern long-eared bat (50th credible bound)	0	68	No

CONCLUSIONS

The post-construction monitoring effort completed in 2022 was consistent with the HCP's monitoring requirements and the Project's 2022 study plan. No Covered Species carcasses were found despite a high probability of detection in 2022. Estimates of potential take for the Covered Species were below the levels authorized by the ITP and no adaptive management was necessary.

REFERENCES

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Second Edition. Springer, New York, New York.

Dalthorp, D. and M. Huso. 2015. A Framework for Decision Points to Trigger Adaptive Management Actions in Long-Term Incidental Take Permits. US Geological Survey Open-File Report 2015-1227. 88 pp. doi: 10.3133/ofr20151227. Available online: https://pubs.usgs.gov/of/2015/1227/ofr20151227.pdf

Dalthorp, D., M. M. P. Huso, and D. Dail. 2017. Evidence of Absence (V2.0) Software User Guide. US Geological Survey (USGS) Data Series 1055. USGS, Reston, Virginia. 109 pp. doi: 10.3133/ds1055. Available online: https://pubs.usgs.gov/ds/1055/ds1055.pdf

Dalthorp, D. H., L. Madsen, M. M. Huso, P. Rabie, R. Wolpert, J. Studyvin, J. Simonis, and J. M. Mintz. 2018. GenEst Statistical Models—a Generalized Estimator of Mortality. US Geological Survey Techniques and Methods, Volume 7, Chapter A2. 13 pp. doi: 10.3133/tm7A2. Available online: https://pubs.usgs.gov/tm/7a2/tm7a2.pdf

Dalthorp, D. H, P. Rabie, M. M. Huso, and A. Tredennick. 2020. Some Approaches to Accounting for Incidental Carcass Discoveries in Non-Monitored Years using the Evidence of Absence Model. US Geological Survey Open-File Report 2020-1027, 24p. Available online: https://pubs.er.usgs.gov/publication/ofr20201027

Esri. 2022. World Imagery and Aerial Photos (World Topo). ArcGIS Resource Center. Environmental Systems Research Institute (Esri), producers of ArcGIS software, Redlands, California. Accessed November 2022. Available online: https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=10df2279f9684e4a9f6a7f08febac2a9

Headwaters Wind Farm LLC in consultation with Western EcoSystems Technology, Inc. Indiana Bat and Northern Long-Eared Bat Final Habitat Conservation Plan for the Headwaters Wind Farm Randolph County, Indiana. April 2019. Available online: https://ecos.fws.gov/ecp/report/conservation-plan?plan_id=4551

Helfers, F. 2017. The Nose Work Handler - Foundation to Finesse. Dogwise Publishing, Wenatchee, Washington. 144 pp.

Huso, M., D. Dalthorp, and F. Korner-Nievergelt. 2017. Statistical Principles of Post-Construction Fatality Monitoring Design. Pp. *In*: M. Perrow, ed. Wildlife and Wind Farms, Conflicts and Solutions. Pelagic Publishing, Exeter, United Kingdom. Vol. 2, Onshore: Monitoring and Mitigation.

Kalbfleisch, J. D. and R. L. Prentice. 2002. The Statistical Analysis of Failure Time Data. John Wiley & Sons, Hoboken, New Jersey.

Kay, D. 2012. Super Sniffer Drill Book - a Workbook for Training Detector Dogs. Coveran Publishing House, 86 pp.

Khokan, M. R., W. Bari, and J. A. Khan. 2013. Weighted Maximum Likelihood Approach for Robust Estimation: Weibull Model. Dhaka University Journal of Science 61(2): 153-156.

McAleander, A., A. Ciecka, A. Tredennick, D. Riser-Espinoza, and S. Howlin. 2022. Post-Construction Monitoring Studies for the Headwaters Wind Farm, Randolph County, Indiana, Final Report: April 1 – October 15, 2021. Prepared for EDP Renewables (EDPR), Houston, Texas. Prepared by WEST, Bloomington, Indiana. January 31, 2022

National Land Cover Database (NLCD). 2019. National Land Cover Database 2019 - Landcover & Imperviousness (NLCD 2019). Available online: https://www.mrlc.gov/data. *As cited* includes:

Homer, C., J. Dewitz, S. Jin, G. Xian, C. Costello, P. Danielson, L. Gass, M. Funk, J. Wickham, S. Stehman, R. Auch, and K. Riitters. 2020. Conterminous United States Land Cover Change Patterns 2001–2016 from the 2016 National Land Cover Database. ISPRS Journal of Photogrammetry and Remote Sensing 162(5): 184-199. doi: 10.1016/j.isprsjprs.2020.02.019.

Jin, S., C. Homer, L. Yang, P. Danielson, J. Dewitz, C. Li, Z. Zhu, G. Xian, and D. Howard. 2019. Overall Methodology Design for the United States National Land Cover Database 2016 Products. Remote Sensing. 2971. doi: 10.3390/rs11242971.

Wickham, J., S. V. Stehman, D. G. Sorenson, L. Gass, and J. A. Dewitz. 2021, Thematic Accuracy Assessment of the NLCD 2016 Land Cover for the Conterminous United States: Remote Sensing of Environment 257: 112357. doi: 10.1016/j.rse.2021.112357.

and

Yang, L., S. Jin, P. Danielson, C. Homer, L. Gass, S. M. Bender, A. Case, C. Costello, J. Dewitz, J. Fry, M. Funk, B. Granneman, G. C. Liknes, M. Rigge, and G. Xian. 2018. A New Generation of the United States National Land Cover Database: Requirements, Research Priorities, Design, and Implementation Strategies. ISPRS Journal of Photogrammetry and Remote Sensing 146: 108-123. doi: 10.1016/j.isprsjprs.2018.09.006. Ohio Department of Natural Resources (ODNR). 2011. Amendment to the on-Shore Bird and Bat Pre- and Post-Construction Monitoring Protocol for Commercial Wind Energy Facilities in Ohio. Available online: https://ohiodnr.gov/static/documents/wildlife/wildlife-management/wind%20%20postconstructionmonitoringprotocol.pdf

R Development Core Team. 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available online: http://www.R-project.org/

Rodriguez, M., A. Tredennick, and K. DuBridge. 2020. Post-Construction Monitoring Studies for the Headwaters Wind Farm, Randolph County, Indiana, Final Report: July 2 – October 15, 2019. Prepared for EDP Renewables (EDPR), Houston, Texas. Prepared by Western EcoSystems Technology, Inc., Bloomington, Indiana. March 11, 2020

US Fish and Wildlife Service (USFWS). 2016. Midwest Wind Energy Multi-Species Habitat Conservation Plan: Public Review Draft. USFWS Midwest Region in collaboration with the States of Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, and Wisconsin and the American Wind Energy Association. April 2016. Available online: https://www.fws.gov/midwest/endangered/permits/hcp/r3wind/DraftHCPandEIS.html

Yee, T. W. 2015. Vector Generalized Linear and Additive Models: With an Implementation in R. New York, USA: Springer

Appendix A. Carcasses found during the 2022 Post-Construction Monitoring Surveys

Appendix A. Carcasses found at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Found Date	Common Name	Distance from Turbine (m)	Turbine	Search Type	Plot Type	Physical Condition	Aided Search
Bats							
04/04/2022	silver-haired bat	3	22	carcass search	twice per month road and pad	scavenged	no
04/06/2022	eastern red bat	10	92	incidental	twice per month road and pad	scavenged	no
05/02/2022	silver-haired bat	21	20	carcass search	twice per month road and pad	scavenged	no
05/05/2022	silver-haired bat	40	72	carcass search	twice per month road and pad	intact	no
05/12/2022	eastern red bat	53	77	incidental	twice per week cleared plot	scavenged	no
05/16/2022	eastern red bat	90	48	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
05/16/2022	silver-haired bat	70	48	carcass search	twice per week cleared plot	dismembered	yes[1]
05/16/2022	silver-haired bat	38	48	carcass search	twice per week cleared plot	scavenged	yes[1]
05/19/2022	silver-haired bat	69	48	carcass search	twice per week cleared plot	dismembered	yes[1]
05/20/2022	eastern red bat	39	39	carcass search	twice per week cleared plot	intact	yes[1]
05/24/2022	hoary bat	64	77	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	big brown bat	44	24	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	big brown bat	55	48	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	eastern red bat	50	71	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	eastern red bat	53	71	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	eastern red bat	69	71	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	silver-haired bat	90	48	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
06/06/2022	eastern red bat	12	24	carcass search	twice per week cleared plot	scavenged	yes[1]
06/06/2022	eastern red bat	56	48	carcass search	twice per week cleared plot	intact	yes[1]
06/07/2022	eastern red bat	5	95	carcass search	twice per week cleared plot	scavenged	yes[1]
06/09/2022	silver-haired bat	23	41	carcass search	twice per week cleared plot	scavenged	yes[1]
06/10/2022	silver-haired bat	37	40	carcass search	twice per week cleared plot	scavenged	yes[1]
06/10/2022	silver-haired bat	38	96	carcass search	twice per week cleared plot	scavenged	yes[1]
06/13/2022	big brown bat	22	79	incidental[2]	n/a	intact	no

Appendix A. Carcasses found at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Found Date	Common Name	Distance from Turbine (m)	Turbine	Search Type	Plot Type	Physical Condition	Aided Search
06/13/2022	hoary bat	43	41	carcass search	twice per week cleared plot	scavenged	yes[1]
06/14/2022	eastern red bat	34	77	carcass search	twice per week cleared plot	scavenged	yes[1]
06/14/2022	silver-haired bat	24	77	carcass search	twice per week cleared plot	scavenged	yes[1]
06/14/2022	silver-haired bat	25	95	carcass search	twice per week cleared plot	scavenged	yes[1]
06/16/2022	eastern red bat	18	70	carcass search	twice per week cleared plot	scavenged	yes[1]
06/16/2022	silver-haired bat	21	24	carcass search	twice per week cleared plot	scavenged	yes[1]
06/16/2022	silver-haired bat	18	70	carcass search	twice per week cleared plot	scavenged	yes[1]
06/17/2022	eastern red bat	57	39	carcass search	twice per week cleared plot	scavenged	yes[1]
06/17/2022	eastern red bat	63	39	carcass search	twice per week cleared plot	scavenged	yes[1]
06/17/2022	hoary bat	68	95	carcass search	twice per week cleared plot	scavenged	yes[1]
06/17/2022	hoary bat	9	96	carcass search	twice per week cleared plot	dismembered	yes[1]
06/17/2022	silver-haired bat	67	96	carcass search	twice per week cleared plot	scavenged	yes[1]
06/21/2022	eastern red bat	59	24	carcass search	twice per week cleared plot	scavenged	yes[1]
06/21/2022	eastern red bat	31	24	carcass search	twice per week cleared plot	scavenged	yes[1]
06/22/2022	eastern red bat	59	96	carcass search	twice per week cleared plot	scavenged	yes[1]
06/22/2022	silver-haired bat	36	40	carcass search	twice per week cleared plot	scavenged	yes[1]
06/22/2022	silver-haired bat	14	40	carcass search	twice per week cleared plot	scavenged	yes[1]
06/22/2022	silver-haired bat	65	40	carcass search	twice per week cleared plot	scavenged	yes[1]
06/23/2022	silver-haired bat	59	48	carcass search	twice per week cleared plot	scavenged	yes[1]
06/24/2022	hoary bat	32	39	carcass search	twice per week cleared plot	intact	yes[1]
06/28/2022	eastern red bat	58	39	carcass search	twice per week cleared plot	scavenged	yes[1]
06/28/2022	eastern red bat	43	39	carcass search	twice per week cleared plot	scavenged	yes[1]
06/28/2022	eastern red bat	17	95	carcass search	twice per week cleared plot	scavenged	yes[1]
07/04/2022	big brown bat	29	70	carcass search	twice per week cleared plot	scavenged	yes[1]
07/08/2022	eastern red bat	42	39	carcass search	twice per week cleared plot	scavenged	yes[1]

Appendix A. Carcasses found at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Found Date	Common Name	Distance from Turbine (m)	Turbine	Search Type	Plot Type	Physical Condition	Aided Search
07/08/2022	eastern red bat	54	95	carcass search	twice per week cleared plot	scavenged	yes[1]
07/10/2022	eastern red bat	40	24	carcass search	twice per week cleared plot	dismembered	yes[1]
07/10/2022	eastern red bat	33	48	carcass search	twice per week cleared plot	scavenged	yes[1]
07/11/2022	eastern red bat	38	39	incidental	twice per week cleared plot	scavenged	yes[1]
07/11/2022	hoary bat	44	96	carcass search	twice per week cleared plot	scavenged	yes[1]
07/16/2022	eastern red bat	23	40	carcass search	twice per week cleared plot	scavenged	yes[1]
07/21/2022	eastern red bat	27	24	carcass search	twice per week cleared plot	scavenged	yes[1]
07/28/2022	hoary bat	51	24	carcass search	twice per week cleared plot	intact	yes[1]
07/29/2022	big brown bat	21	96	carcass search	twice per week cleared plot	scavenged	yes[1]
07/29/2022	eastern red bat	32	77	carcass search	twice per week cleared plot	scavenged	yes[1]
08/16/2022	big brown bat	9	74	incidental[2]	n/a	intact	no
Birds							
04/04/2022	horned lark	5	13	carcass search	twice per month road and pad	scavenged	no
04/04/2022	horned lark	17	23	carcass search	twice per month road and pad	intact	no
04/07/2022	American kestrel	8	100	incidental	twice per month road and pad	intact	no
05/02/2022	pine warbler	95	18	carcass search	twice per month road and pad	intact	no
05/12/2022	horned lark	48	77	incidental	twice per week cleared plot	scavenged	no
05/13/2022	red-tailed hawk	12	25	incidental	twice per week road and pad	scavenged	no
05/16/2022	chestnut-sided warbler	82	48	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
05/16/2022	unidentified passerine	102	48	carcass search[2]	twice per week cleared plot	dismembered	yes[1]
05/19/2022	red-winged blackbird	2	70	carcass search	twice per week cleared plot	dismembered	yes[1]
05/20/2022	red-tailed hawk	68	77	carcass search	twice per week cleared plot	dismembered	yes[1]
05/23/2022	red-eyed vireo	79	71	carcass search[2]	twice per week cleared plot	scavenged	yes[1]

Appendix A. Carcasses found at the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Found Date	Common Name	Distance from Turbine (m)	Turbine	Search Type	Plot Type	Physical Condition	Aided Search
05/24/2022	red-eyed vireo	40	40	carcass search	twice per week cleared plot	scavenged	yes[1]
06/02/2022	yellow-billed cuckoo	90	48	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
06/13/2022	horned lark	22	22	incidental[2]	n/a	scavenged	no
07/04/2022	purple martin	73	24	carcass search[2]	twice per week cleared plot	intact	yes[1]

[1] dog aided search

[2] Carcass was found outside the search area and/or outside study period

Appendix B. Searcher Efficiency and Carcass Persistence Model Fitting Results

Appendix B1. Searcher efficiency models for 70-meter plots at the Headwaters Wind Farm, Randolph County, Indiana from April 1, 2022 to July 31, 2022 (n=21).

Covariates	k Value	AICc	Delta AICc
No covariates	0.67	22.66	0[1]

[1] Selected model.

AICc = Corrected Akaike Information Criterion.

Delta AICc = Change in AICc

Appendix B2. Searcher efficiency models for road and pad plots at the Headwaters Wind Farm, Randolph County, Indiana from April 1, 2022 to July 31, 2022 (n = 32).

Covariates	k Value	AICc	Delta AICc
No Covariates	0.67	29.87	0[1]
Season	0.67	32.15	2.28

[1] Selected model.

AICc = Corrected Akaike Information Criterion.

Delta AICc = Change in AICc

Appendix B3. Carcass persistence models with covariates and distributions for bats at the Headwaters Wind Farm, Randolph County, Indiana from April 1, 2022 to July 31, 2022 (n = 45).

Location Covariates	Scale Covariates	Distribution	AICc	Delta AICc
Season	No Covariates	lognormal	185.72	0
Season	No Covariates	loglogistic	185.78	0.06
Season	Season	loglogistic	185.87	0.15
Season	Season	lognormal	185.96	0.24
PlotSearchType	No Covariates	lognormal	186.12	0.40
PlotSearchType	No Covariates	loglogistic	186.26	0.54
Season	No Covariates	Weibull	186.33	0.61
Season + PlotSearchType	No Covariates	lognormal	186.96	1.24
Season + PlotSearchType	No Covariates	loglogistic	187.12	1.40
Season + PlotSearchType	Season	lognormal	187.43	1.71
Season + PlotSearchType	Season	loglogistic	187.44	1.72
Season + PlotSearchType	No Covariates	Weibull	187.48	1.76
No Covariates	No Covariates	lognormal	187.59	1.87[1]
No Covariates	No Covariates	loglogistic	187.61	1.89
PlotSearchType	No Covariates	Weibull	187.66	1.94
PlotSearchType	PlotSearchType	lognormal	187.89	2.17
PlotSearchType	PlotSearchType	loglogistic	188.04	2.32
No Covariates	Season	lognormal	188.05	2.33
No Covariates	Season	loglogistic	188.10	2.38
Season	Season	Weibull	188.15	2.43
Season	Season + PlotSearchType	loglogistic	188.40	2.68

Season	Season + PlotSearchType	lognormal	188.50	2.78
PlotSearchType	Season + PlotSearchType	lognormal	188.58	2.86
Season + PlotSearchType	PlotSearchType	lognormal	188.69	2.97
PlotSearchType	Season + PlotSearchType	loglogistic	188.74	3.02
Season + PlotSearchType	PlotSearchType	loglogistic	188.82	3.10
No Covariates	PlotSearchType	lognormal	188.90	3.18
No Covariates	PlotSearchType	loglogistic	188.92	3.20
Season + PlotSearchType	Season	Weibull	189.48	3.76
Season + PlotSearchType	PlotSearchType	Weibull	189.82	4.10
No Covariates	No Covariates	Weibull	189.92	4.20
PlotSearchType	PlotSearchType	Weibull	189.97	4.25
Season + PlotSearchType	Season + PlotSearchType	lognormal	190.04	4.32
Season + PlotSearchType	Season + PlotSearchType	loglogistic	190.05	4.33
No Covariates	Season + PlotSearchType	lognormal	190.18	4.46
No Covariates	Season + PlotSearchType	loglogistic	190.23	4.51
Season	Season + PlotSearchType	Weibull	190.67	4.95
PlotSearchType	Season + PlotSearchType	Weibull	191.72	6.00
No Covariates	Season	Weibull	191.99	6.27
No Covariates	PlotSearchType	Weibull	192.01	6.29
Season + PlotSearchType	Season + PlotSearchType	Weibull	192.14	6.42
No Covariates	Season + PlotSearchType	Weibull	194.31	8.59
Season	-	exponential	210.73	25.01
Season + PlotSearchType	-	exponential	211.25	25.53
PlotSearchType	-	exponential	214.50	28.78
No Covariates	-	exponential	219.79	34.07

[1] Selected model

AICc = Corrected Akaike Information Criterion

Delta AICc = Change in AICc

Appendix B4. Carcass persistence top model with covariates, distributions, and model parameters for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Size Class	Distribution	Estimated Median Removal Times (days)	Parameter 1	Parameter 2
Bat	Lognormal[1]	5.10	meanlog = 1.63	sdlog = 2.592

[1] Parameterization follows the base R parameterization for this distribution.

Appendix C. Truncated Weighted Likelihood (TWL) Area Adjustment Model Fitting Results

Appendix C1. Number and percent (%) of bat carcasses found and total included in the area adjustment calculation for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

	Included in Area Adjustment		Outside Search Area[1]		Outside Study Period[1]		Total	
Species	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
eastern red bat	25	49.02	1	25.00	2	40.00	28	46.67
silver-haired bat	15	29.41	1	25.00	3	60.00	19	31.67
hoary bat	7	13.73	0	0	0	0	7	11.67
big brown bat	4	7.84	2	50.00	0	0	6	10.00
Total	**51**	**100**	**4**	**100**	**5**	**100**	**60**	**100**

[1] Carcasses outside of search area or study period not included in analysis

Appendix C2. Search area adjustment models for bats from the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022.

Distribution	AICc	Delta AICc
Weibull	1,076.85	0[1]
normal	1,078.83	1.98
gamma	1,084.39	7.54
Gompertz	1,085.73	8.88
Rayleigh	1,089.02	12.17

[1] Selected model

Appendix C3. Truncated weighted maximum likelihood search area adjustment estimates for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022 (Bat n=51).

Size Class	Search Area Type	Distribution	Season	Parameter 1	Parameter 2	Area Adjustment
Bat	full plot	Weibull	Summer	2.6655	42.4906	0.96
	road and pad[1]	Weibull	Spring	2.6655	42.4906	0.09
	road and pad[2]	Weibull	Summer	2.6655	42.4906	0.07

[1] All plots were searched as road and pad plots in the spring.

[2] Only one road and pad plot was searched during the summer season.

Appendix D. Inputs for Single Class and Multiple Class Modules in Evidence of Absence

Appendix D1. Inputs needed to run Evidence of Absence: Single Class Module for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022[1]

					Searcher Efficiency		Carcass Persistence[2]	
Season	Plot Type	Search Interval (I)	Number of Searches	Spatial Coverage (a)	Carcasses Available	Carcasses Found	Shape (α)	Scale (β)
Spring	100-m road and pad	14	4	0.09	29	25	6.72	1.63
Summer	100-m road and pad	4	21	0.07	29	25	6.72	1.63
Summer	70-m full plot	3.5	22	0.96	24	19	6.72	1.63

[1] *k* was assumed to equal 0.67 for all strata, per Huso et al. (2017).

[2] A lognormal distribution was used for carcass persistence on both 100-m road and pad plots and 70-m full plots. The 95% upper and lower confidence intervals on β were set to 0.82, 2.44.

m = meter

Appendix D2. Inputs needed to run Evidence of Absence model to combine across plot types within each season: Multiple Class Module for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022

Season	Plot Type	Ba	Bb	Within-Season Sampling Fraction
Spring	100-m road and pad	50.02	1186.15	1.0
Summer	100-m road and pad	109.9	2303.49	0.09
Summer	70-m full plot	40.65	28.29	0.91

m = meter

Appendix D3. Inputs needed to run Evidence of Absence model to combine across seasons: Multiple Class Module for the Headwaters Wind Farm, Randolph County, Indiana, from April 1 – July 31, 2022

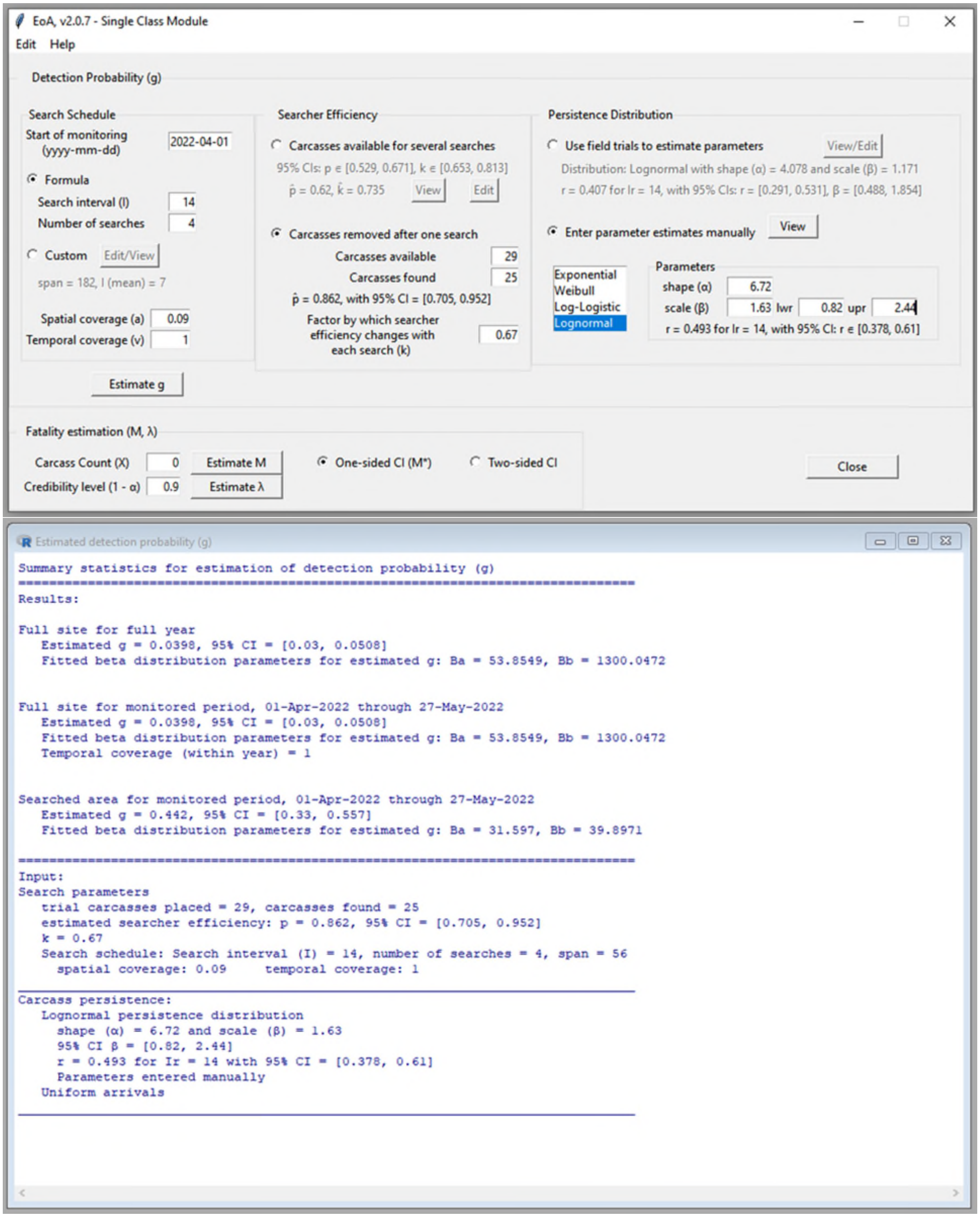
Season	Ba	Bb	Weights (DWP[1])
Spring (April 1–May 15)	50.02	1186.15	0.64
Summer (May 16–July 31)	46.39	39.48	0.36

[1] DWP = Density-weighted proportion

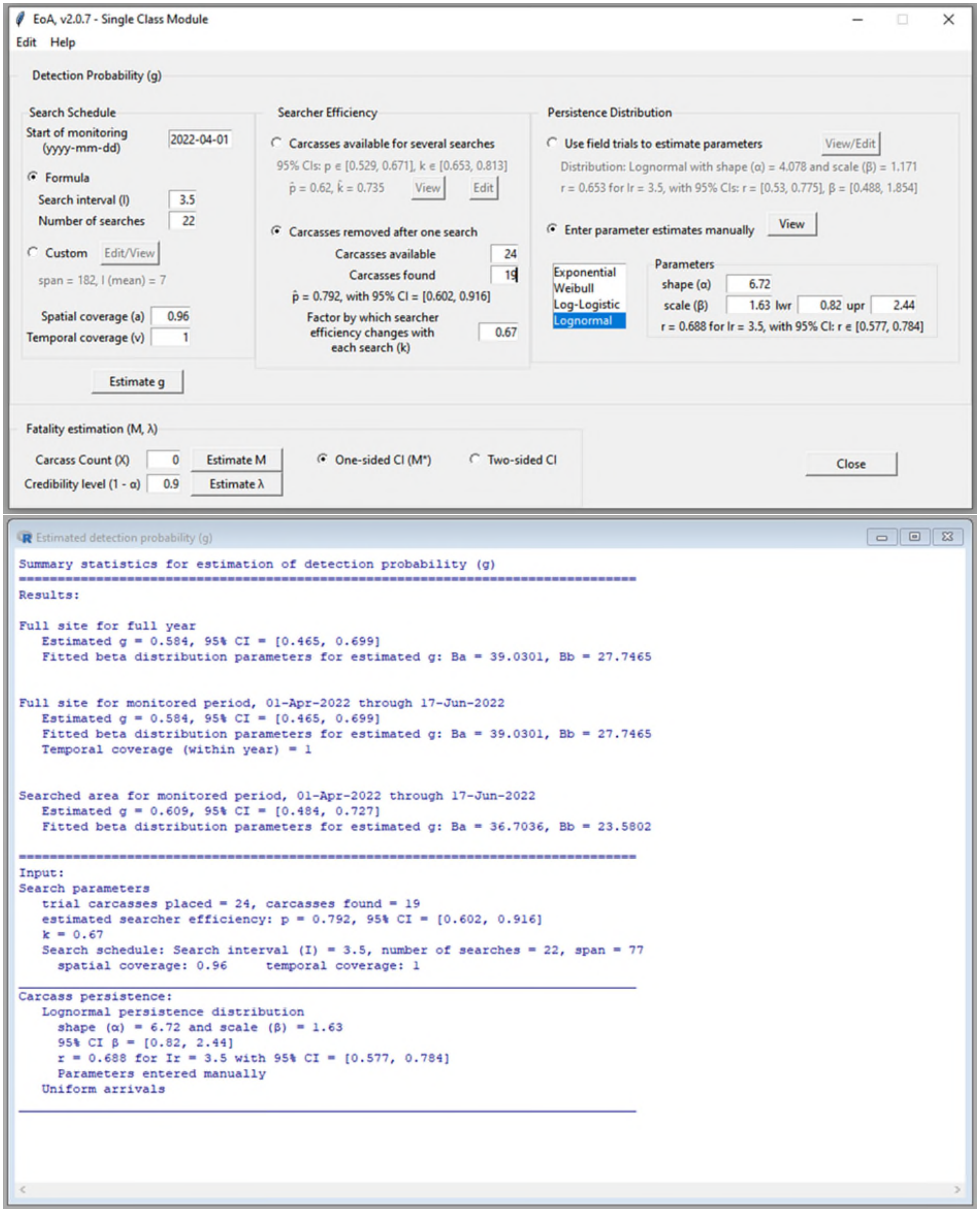
Appendix D4. Inputs needed to run Evidence of Absence model to combine across years: Multiple Years Module for the Headwaters Wind Farm in Randolph County, Indiana, from 2019 – 2022.

Year	Ba	Bb	Weights (ρ)
2019	26.57	97.63	0.88
2020	522.96	1728.37	1.0
2021	304.41	576.54	0.91
2022	98.54	348.59	0.16

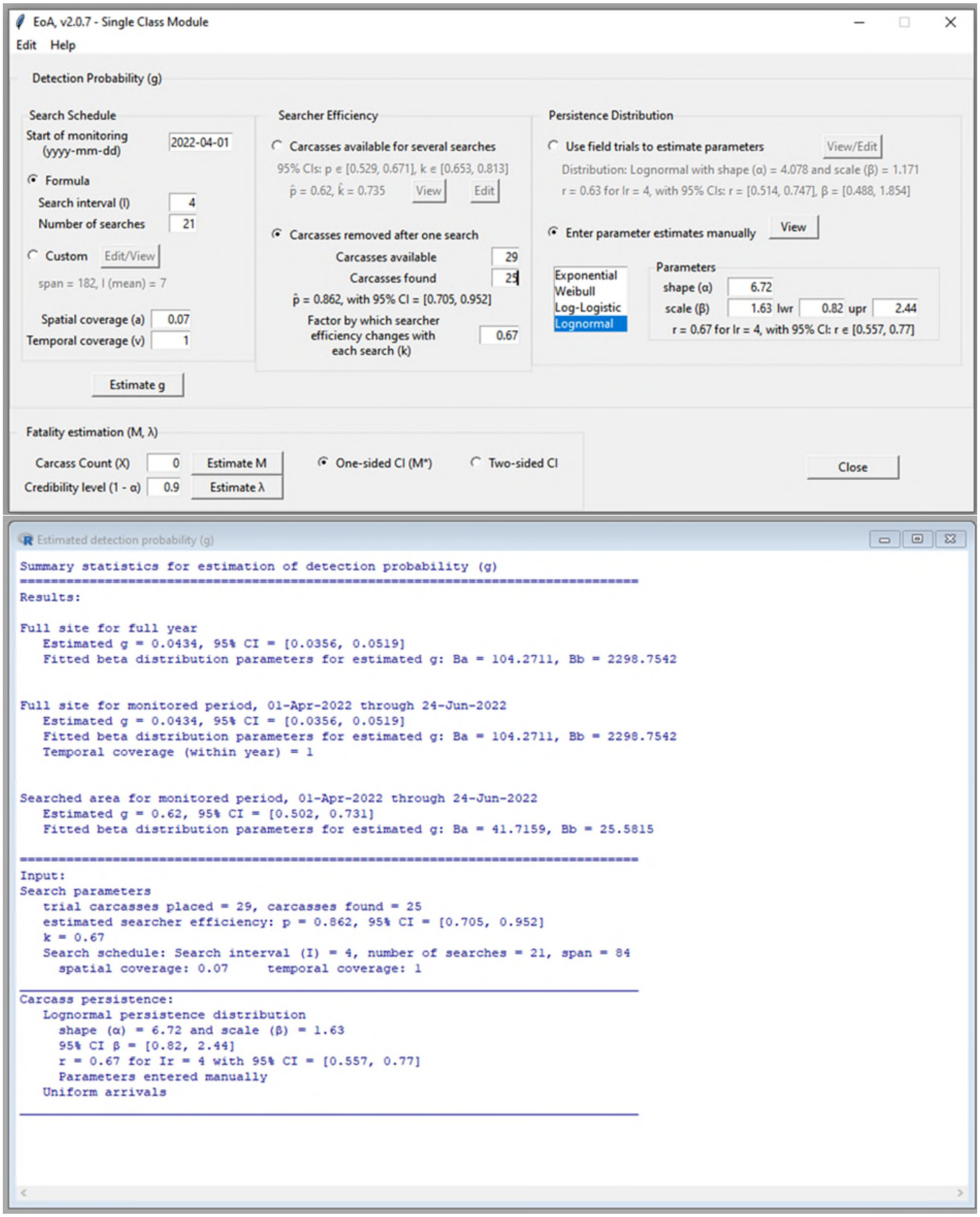
Appendix E. Screenshots of Inputs for Single Class and Multiple Class Modules in Evidence of Absence



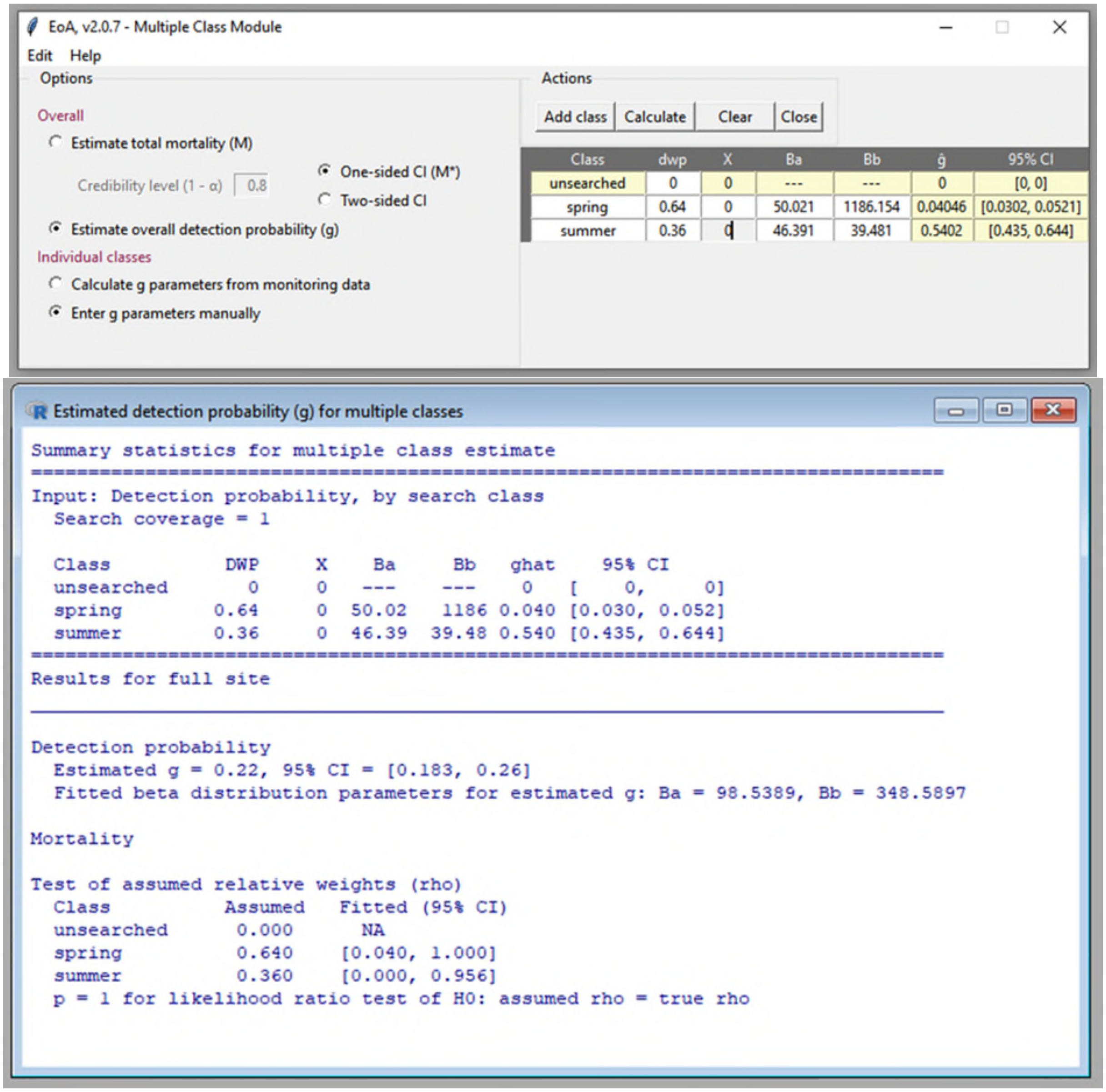
Appendix E1. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Spring 2022, 100-meter road and pad searches at 100 turbines with a blade length of 55 meters, searched at a 14-day interval.



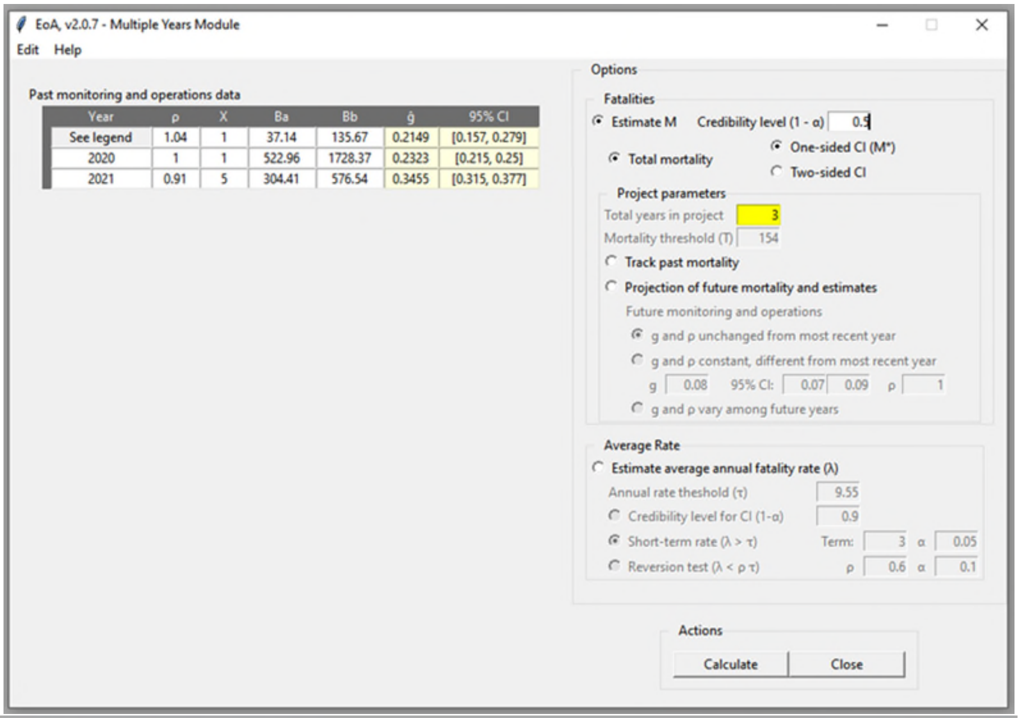
Appendix E2. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Summer 2022, 70-meter full plot searches at 11 turbines with a blade length of 55 meters, searched at a 3.5-day interval.

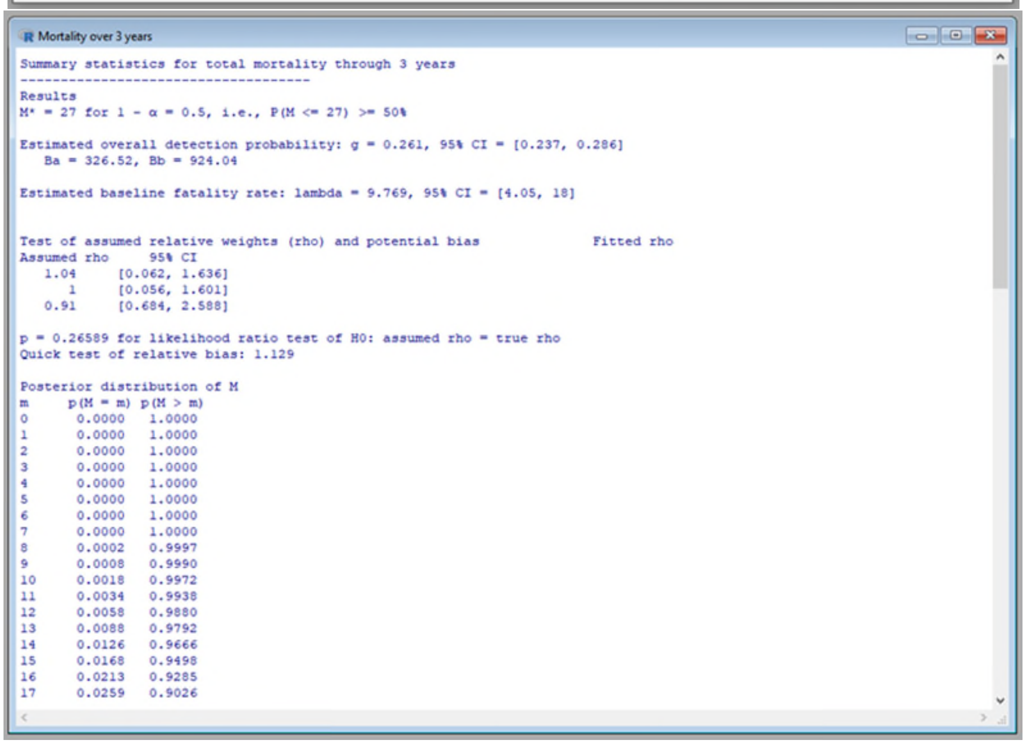


Appendix E3. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Summer 2022, 100-meter road and pad searches at 1 turbine with a blade length of 55 meters, searched at a 3.5-day interval.



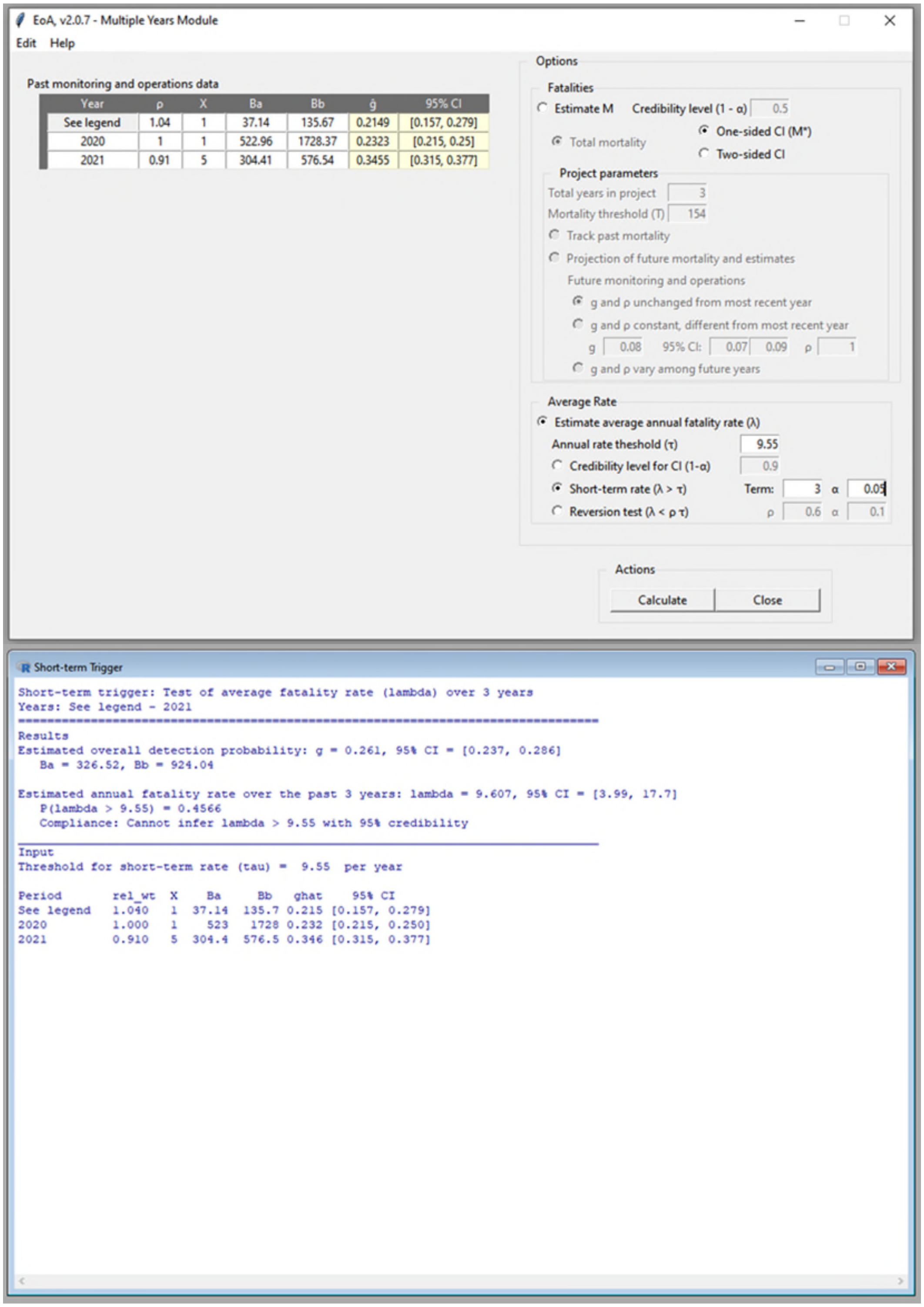
Appendix E4. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Multiple Class Module inputs and output for Spring and Summer 2022, (n=100 in spring, 11 in summer), searched at a 14-day interval in the spring and a 3.5-day interval in the summer.



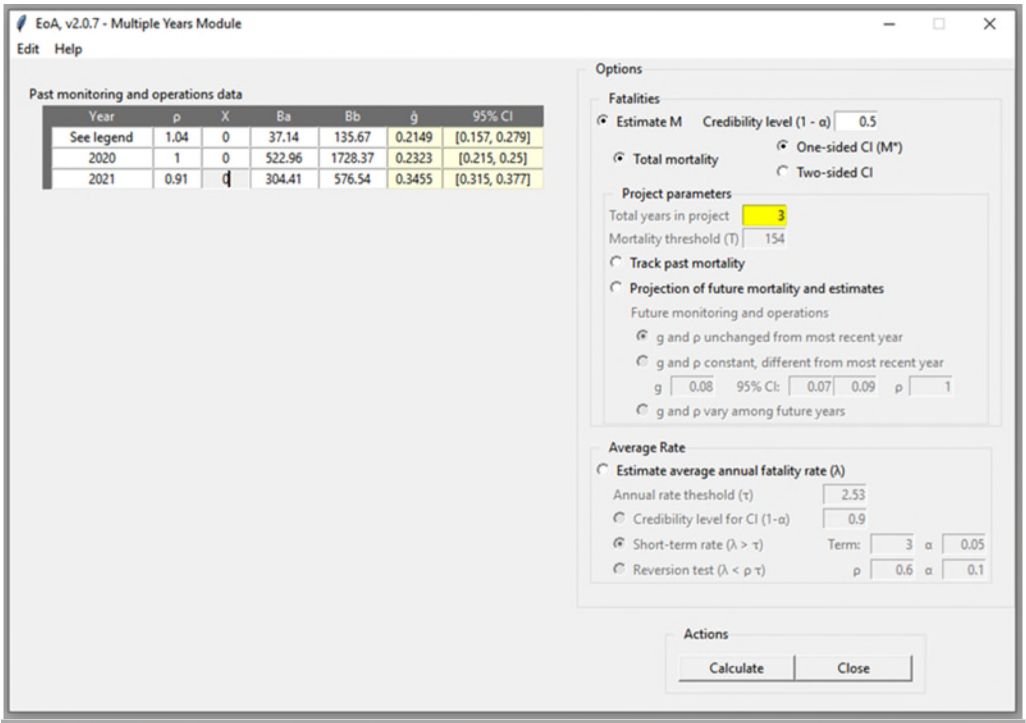


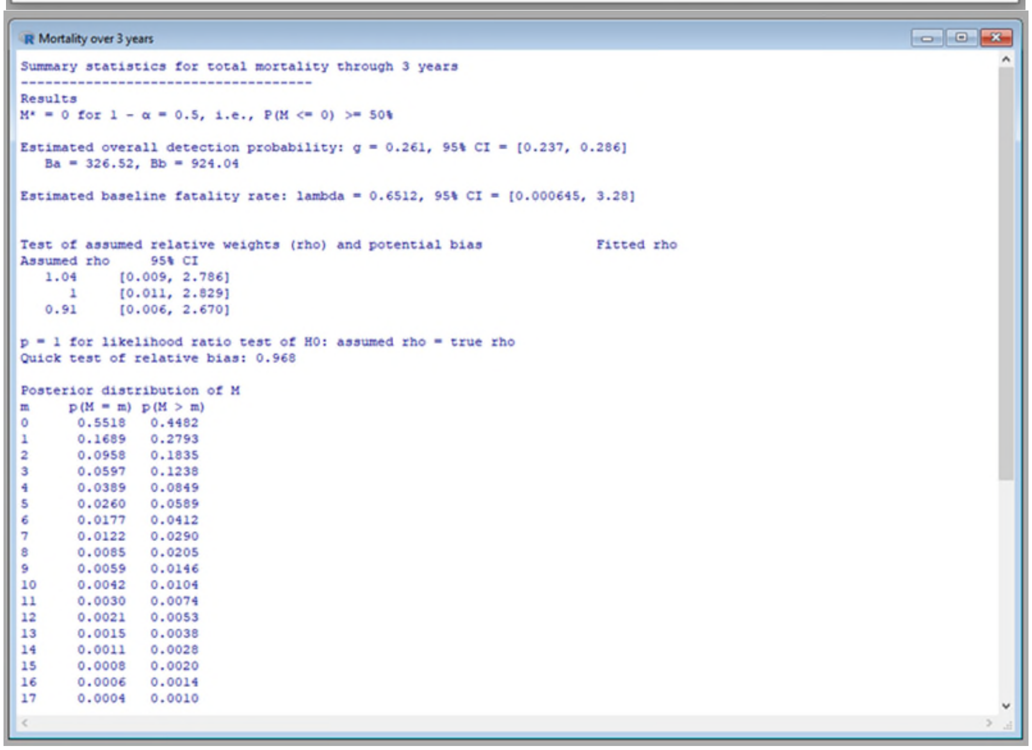
Appendix E5. Multiple years M* Indiana bat.

**Due to the limitations of the EoA GUI with 2 study periods that don't encompass a full monitoring year, we combined the 2019 and 2022 study periods into one full monitoring year. Rho values of 0.88 in 2019 and 0.16 in 2022 were summed for a combined rho value of 1.04 for this stratum. We used these 3 full study periods to estimate lambda and M*, as well as to evaluate the short term and long term triggers. The alpha and beta parameters for combined 2019 and 2022 monitoring periods were obtained by using the multiple class module to combine g values. The multiple class module requires the weights to sum to 1.0, so the 0.88 and 1.06 values were rescaled by dividing by 1.04.*



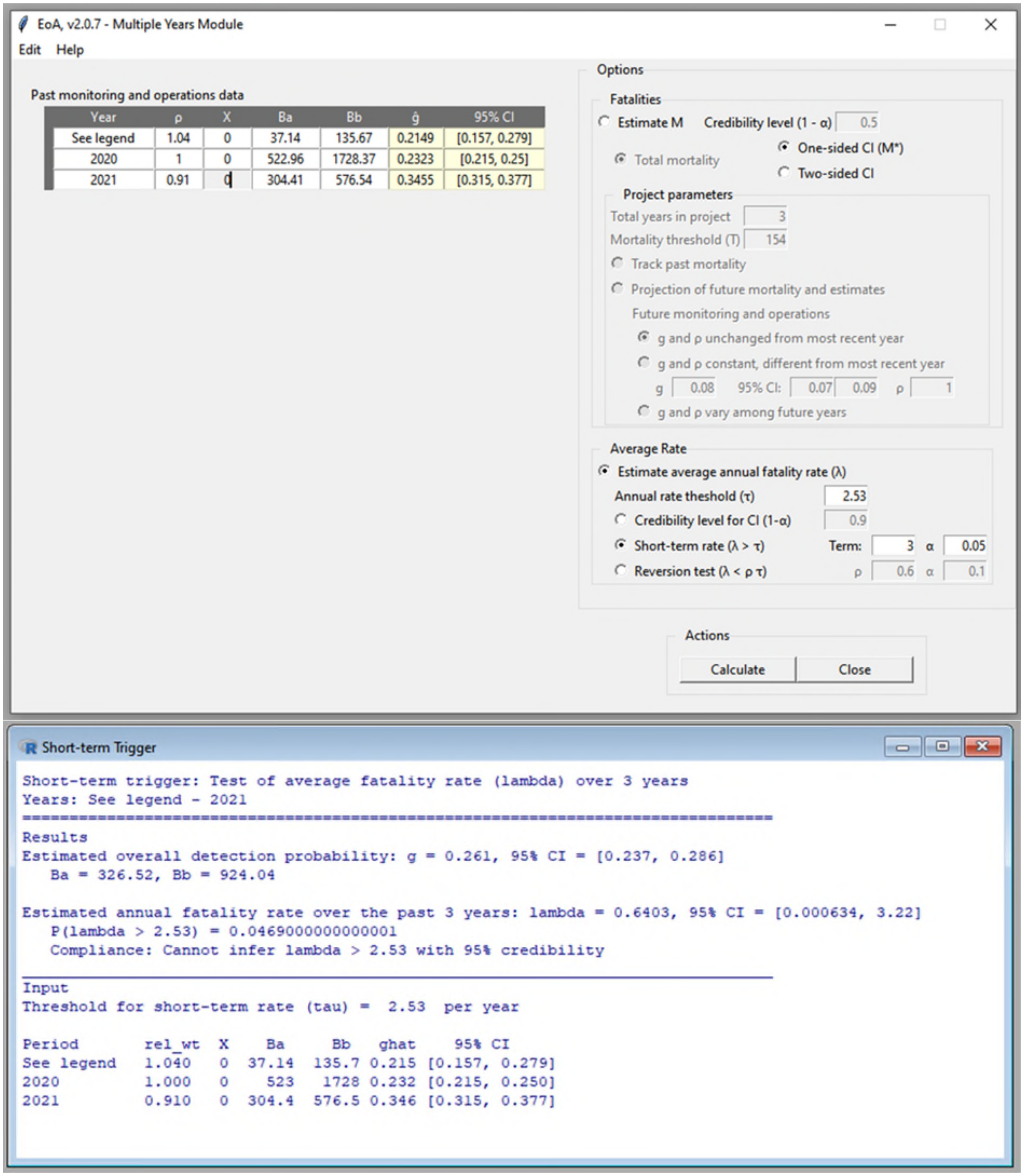
Appendix E6. Lambda Indiana bat





Appendix E7. M* northern long-eared bat

**Due to the limitations of the EoA GUI with 2 study periods that don't encompass a full monitoring year, we combined the 2019 and 2022 study periods into one full monitoring year. Rho values of 0.88 in 2019 and 0.16 in 2022 were summed for a combined rho value of 1.04 for this stratum. We used these 3 full study periods to estimate lambda and M*, as well as to evaluate the short term and long term triggers. The alpha and beta parameters for combined 2019 and 2022 monitoring periods were obtained by using the multiple class module to combine g values. The multiple class module requires the weights to sum to 1.0, so the 0.88 and 1.06 values were rescaled by dividing by 1.04.*



Appendix E8. Lambda northern long-eared bat