Post-construction Monitoring Study for the Hog Creek Wind Farm Hardin County, Ohio

Year 4 Report

April 1 – May 15, 2023

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WEST

EXECUTIVE SUMMARY

Hog Creek Wind Project, LLC (Hog Creek) is operating the Hog Creek Wind Farm (Project). This report details the post-construction monitoring (PCM) study conducted in 2023, consistent with the Project's Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP; TE80697D-0) for Indiana and northern long-eared bats (Covered Species). Turbines were operated to feather turbine blades under manufacturer's cut-in speed per the Project's HCP.

PCM was completed in accordance with the study plan, which was approved by the US Fish and Wildlife Service on March 14, 2023. The study plan was designed to achieve a 25% probability of detecting a single bat carcass (probability of detection [*g*] of 0.25) for the 29 operational wind turbines at the Project. One turbine was not included in the study plan or searched because it was non-operational during the monitoring period. The overall goal of this PCM 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 by technicians at two plot types: 70-meter (m; 230-foot [ft]) full plots and 100-m (328-ft) expanded road and pads (i.e., gravel road and pads with a 10-m [33-ft] buffer). Searcher efficiency and carcass persistence trials were also conducted to correct for detection and scavenger bias.

No Covered Species were found at the Project. Twenty-two bat carcasses were found during the study. The bat species found were the silver-haired bat (90.9%) and the eastern red bat (9.1%). Two bird carcasses were recorded; no federally or state-listed birds were found.

The *g* was 0.262 (90% confidence interval: 0.213–0.313). Based on the data collected to date (2020 – 2023), the EoA model estimated mean annual fatality rates were 0.79 Indiana bat and 0.79 northern long-eared bat. The probability that the annual take rate exceeded the expected annual take rate was 0.04 for Indiana bat and 0.26 for northern long-eared bat. The cumulative take estimates through 2023 were zero 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.

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INTRODUCTION

Hog Creek Wind Farm, LLC (Hog Creek), a subsidiary of EDP Renewables North America LLC (EDPR), is operating the Hog Creek Wind Farm (Project) in Hardin County, Ohio. EDPR obtained an Incidental Take Permit (ITP; TE80697D-0, dated August 13, 2020) for the federally listed as endangered Indiana bat (*Myotis sodalis*) and northern long-eared bat[1] (*M. septentrionalis*; hereafter Covered Species) from the US Fish and Wildlife Service (USFWS). The Project has completed one fall-only study period (August 15 – October 15, 2020) and two full periods (April 1 – May 15 and August 1 – October 15, 2021 and 2022) of compliance monitoring. This report presents the results of the final, spring-only, study period of compliance monitoring conducted under the ITP, from April 1 – May 15, 2023, to complete three full study periods of monitoring. 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; Hog Creek Wind Project LLC 2020) and determine if adaptive management was 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 96.5% of the Permit Area. The next most common land cover is deciduous forest, which covers 2.7% of the site. All other land cover types collectively make up less than 1.0% of the total land cover (Figure 1; National Land Cover Database 2019).

The Project became fully operational in 2017 and consists of 30 2.2-megawatt (MW) Vestas V110 wind turbines that have a 95-m (312-ft) hub height and a 55-m (180-ft) blade length (Figure 1). All turbines are within the migratory range of the Covered Species, and EDPR adjusted turbine operations to minimize impacts to the Covered Species (Table 1).

[1.] The northern long-eared bat was listed as threatened when the Incidental Take Permit was received. Its status changed to endangered on March 31, 2023 (US Fish and Wildlife Service 2023).

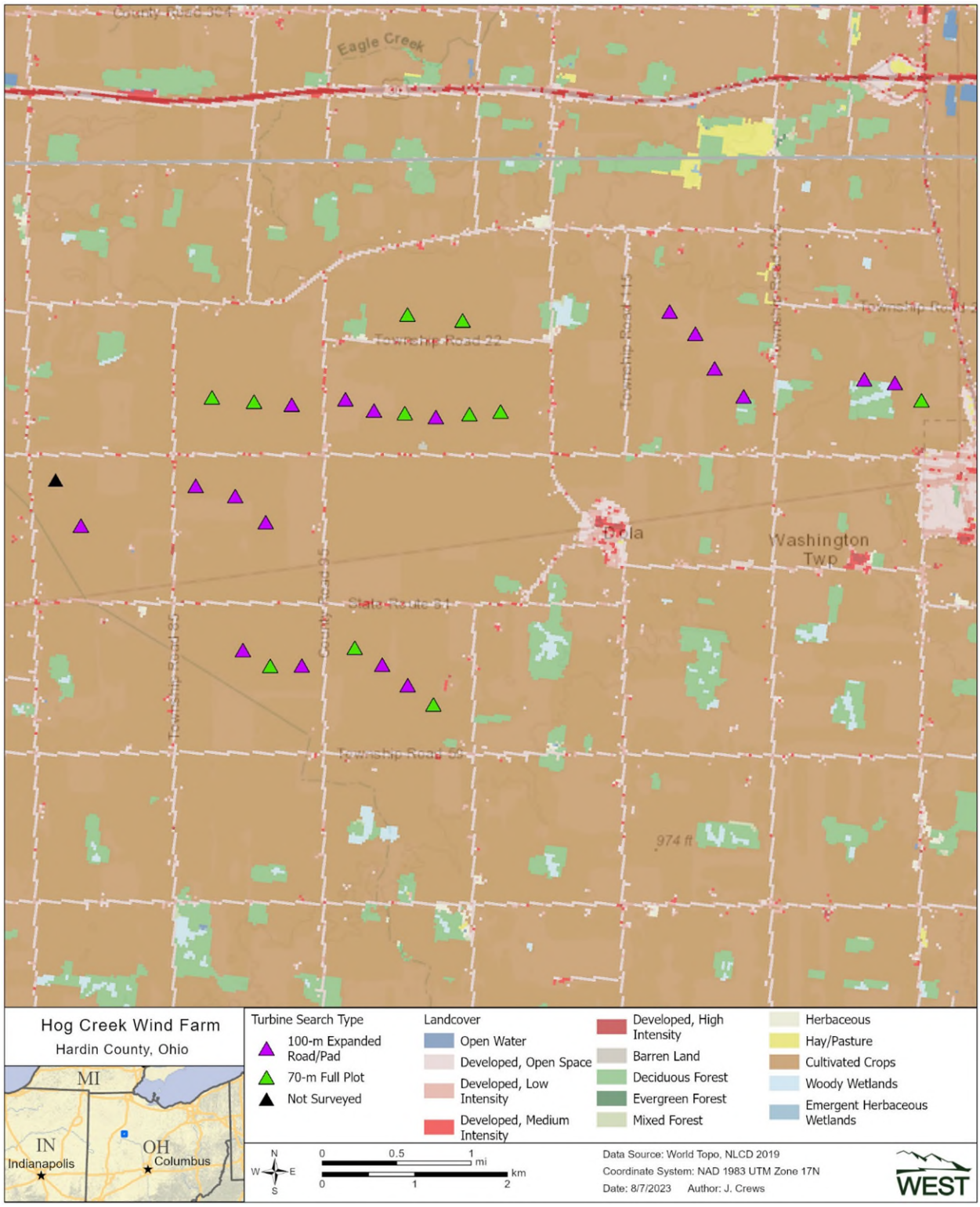

Figure 1. Turbine locations, spring turbine plot types, and surrounding land cover at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Table 1. Seasonal turbine operations regime at the Hog Creek Wind Farm, Hardin County, Ohio.

Season	Turbines	Time of Day	Cut-In Speed (m/s)	Feathering Below Cut-In[1]?	Temperature Threshold[2]
Spring (April 1 – May 15)	All	0.5 hour before sunset to 0.5 hour after sunrise	3.0	Yes	10°C
Summer (May 16 – July 31)	All	0.5 hour before sunset to 0.5 hour after sunrise	3.0	Yes	None
Fall (August 1 – October 15)	All	0.5 hour before sunset to 0.5 hour after sunrise	5.0	Yes	10°C
Winter (October 16 – March 31)	All	Normal turbine operation[3]			

1. Feathering means that turbine blades are 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 of 10 degrees Celsius (50 degrees Fahrenheit). In practice, the Project feathered on all nights regardless of temperature.
3. The manufacturer's cut-in wind speed is 3.0 meters/second (m/s; 9.8 feet/second) across the Project turbines.

METHODS

Western EcoSystems Technology, Inc. (WEST) used Project-specific data from previous post-construction monitoring (PCM) studies at the Project to develop a study plan that targeted a probability of detection (*g*) of 0.25 (Matteson et al. 2022, Hale et al. 2023) to meet the monitoring commitments in the HCP. WEST submitted a study plan to EDPR on February 3, 2023, and EDPR received approval from the USFWS on March 14, 2023 (K. Lott, USFWS, pers. comm.).

Standardized Carcass Searches

Number of Turbines Sampled, Search Frequency, and Plot Size

Technicians conducted standardized carcass searches from April 1 – May 15, 2023, at 29 of the 30 turbines at the Project, searching a combination of expanded road and pads and full plots (Figure 1). Turbine 19 was not searched because it was non-operational during the monitoring period. Technicians searched 18 turbines as 100-m expanded road and pads twice weekly (Table 2). Expanded road and pads consisted of the gravel road and pad areas as well as a 10-m (33-ft) buffer around the gravel areas that were searched to a maximum of 100 m from the turbine base. Technicians searched 11 turbines within a 70-m (230-ft) radius of the turbine as a full plot twice weekly (Table 2). The full plots and buffer areas of the expanded road and pads were not mowed because surveys began before planting season and concluded before vegetation grew to a height that substantially impacted visibility of carcasses.

Table 2. Search effort during spring 2023 at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Plot Type	Plot Radius (m)	Number of Turbines	Search Interval (days)	Searcher Type
Expanded road and pad	100	18	3.5	Technician
Full plot	70	11	3.5	Technician

m = meter.

Search Methods

WEST used technicians to conduct visual searches for carcasses. All personnel were trained to follow 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.

Expanded Road and Pad Searches

Technicians walked transects spaced five m (16 ft) apart at a rate of approximately 45–60 m 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 fatalities on both sides of the transects out to 2.5 m (8.2 ft) to ensure full visual coverage of each search area (Figure 2). Once the gravel road and pad area was searched, an additional 10-m (32-ft) wide transect was walked within a buffer area of cropland parallel to the gravel (Figure 3). The center of the 10-m-wide transect was five m from the edge of the gravel, and technicians visually scanned for carcasses five m on each side of the transect for coverage of the search area.

Figure 2. Representative photo of conditions on gravel of a 100-meter expanded road and pad plot at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Figure 3. Representative photo of conditions on the buffer area of a 100-meter expanded road and pad at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Plot Searches

Technicians visually searched within 70 m of the turbine base for fatalities by walking transects spaced five m apart at a rate of approximately 45–60 m/min (Figure 4). During the search, both sides of the transects were scanned out to 2.5 m to ensure full visual coverage of the entire search plot.

Figure 4. Representative photo of vegetation conditions in a 70-meter full plot at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

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 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 a 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 to three 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), 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—10 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 (TE80697D-0), WEST's Federal Native Endangered and Threatened Species Recovery Permit (ES234121), and WEST's State Scientific Collection Permit (SC210040). 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 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. Any 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 the 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. The USFWS and the Ohio Department of Natural Resources (ODNR) would have been notified within 24 hours of positive identification of any state- or federally listed species, but none were identified during the searches. A permitted bat biologist (ESPER0039249) verified the identifications of all bat carcasses via photos at the end of the surveys and WEST staff delivered the carcasses to the ODNR District 1 field office in Columbus, Ohio, on July 19, 2023.

Bias Trials

Searcher Efficiency Trials

The objective of the searcher efficiency (SEEF) trials was to estimate the probability that a carcass was found by searchers. SEEF trials were conducted in the same areas where carcass searches occurred. Technicians conducting carcass surveys did not know when SEEF trials were being conducted or the location of the trial carcasses. Trial carcasses consisted of eastern red bats (*Lasiurus borealis*), hoary bats (*L. cinereus*), big brown bats (*Eptesicus fuscus*), and silver-haired bats (*Lasionycteris noctivagans*) that had previously been found on site or provided by ODNR. Seventy-eight bat carcasses were placed across plot types to account for potential differences in SEEF on expanded road and pads compared to full plots.

Multiple trials were conducted to measure potential changes in plot conditions on SEEF over the survey period. Each trial carcass was discreetly marked with a black zip-tie around the upper forelimb for identification as a study carcass after it was found. Carcasses were dropped from waist height or higher and allowed to land in a random posture. 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. Technicians did not know when the trial administrator placed carcasses.

Technicians had one chance to locate trial carcasses during the first search after carcass placement. The number and location of trial carcasses found during the search were recorded, and the number of trial carcasses available for detection was determined immediately after each trial by the person responsible for distributing the carcasses. Fifty trial carcasses were left in place to be used for carcass persistence trials (CPT).

Carcass Persistence Trials

The objective of CPT 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. Twenty-five carcasses were planned for each plot type to incorporate the potential effects of varying weather and scavenger densities on carcass persistence. No more than two trial carcasses were placed on a plot during the same trial period 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. The carcasses were checked daily for the first four days, then on days 7, 10, 14, 21, and 30. Trial carcasses were monitored until they were completely removed or the trial period ended.

Search Area Mapping

The boundaries of 100-m road and pads had been mapped using sub-meter Global Positioning System (GPS) units in prior monitoring years. A 10-m (33-ft) radius projection was applied to previously collected road and pads to account for the expanded search area. Technicians recorded the boundaries of 70-m full plots using a Juniper Systems Geode GNS3 sub-meter GPS

unit. The plot boundaries were used to verify if carcasses were found inside the search areas and to inform the distribution of carcasses around turbines.

Quality Assurance and Quality Control

Quality assurance and quality control 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 database was developed to store, organize, and retrieve survey data. All data forms and electronic data files were retained for reference.

Statistical Analysis

The EoA (Dalthorp et al. 2017) modeling framework was used to estimate take of the 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, the searched area adjustment ("DWP" in the software), the results of SEEF and CPT, the seasonal arrival distribution of bats (described below), and the detection reduction factor (*k*; described below).

Searcher Efficiency Estimation

EoA uses raw SEEF data (e.g., number of found and available trial carcasses) to inform overall probability of detection. To determine if searcher efficiency data should be pooled or separated by strata such as plot type or vegetation cover (gravel vs. non-gravel), WEST modeled SEEF using logistic regression. 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. SEEF data were input into the EoA software according to the model selection results.

The change in SEEF 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 that was missed on the first search would never be found on subsequent searches. A *k* of one implies SEEF remained 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 CPT 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, loglogistic, lognormal, and Weibull distributions (Kalbfleisch and Prentice 2002, Dalthorp et al. 2018). Plot type and vegetation cover were included 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% Confidence Interval [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. 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. 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, and Weibull (parameterized according to R Development Core Team [2023] and Yee [2010]). The best model was selected using AICc.

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 on a plot incidentally (e.g., found by maintenance personnel) were included in the analysis if that plot had a scheduled search in the future, but within the same season. If a fatality 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 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 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 *g* for the 2023 study period was estimated using the bias corrections for SEEF, carcass persistence, and area searched. In prior study periods with standardized carcass searches in both spring and fall, the assumed seasonality of risk for the Covered Species, which per the HCP, was 11% in the spring and 89% in the fall, was also used to estimate *g*. The seasonal risk is used to weigh the contributions of detection probability from different seasons in the overall *g* estimate.

Differences in the level of turbine operations (e.g., turbines down for maintenance for extended periods within a season) were also considered.

The EoA Single Class module was used to estimate the detection probability in each search stratum. 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 100-m expanded road and pads), with weights for each class ("DWP" in the software) defined by the within-season sampling fraction. The beta distribution parameters were set to Ba = 0.01 and Bb = 1,000 (a detection probability of 10^{-5}) for unsearched areas within each stratum.

Furthermore, the Multiple Years Module was used to estimate the site-wide, cumulative detection probability for the four monitoring study periods (2020 – 2023). The EoA Multiple Years Module requires the input ρ, which weights the years appropriately for combining beta distribution parameters. The value for ρ was set to 0.7 for 2020 because the ITP was issued part way through summer, meaning about 70% of total annual risk was observed in monitoring data from 2020. In 2021 and 2022, the Project was fully operational for all seasons, so ρ was set to 1.00. In 2023, ρ was set to 0.106 as monitoring was only conducted during the spring and one of the 30 turbines was not operational for the entire study period. 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 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[2].

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 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 determine if an adaptive management response is 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 = 0.1, per the HCP. The Project's short-term trigger is designed to evaluate a rolling window of six years of PCM data. If, within any 6-year rolling window, the estimated take rate exceeds the expected take rate with 90% 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

2. There may be very 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.

median cumulative take estimate (*M**) remains within the permitted limit over the ITP term. Data from four monitoring study periods were used in this analysis (2020 – 2023) along with the values of ρ listed above (0.70, 1.00, 1.00, 0.106, respectively). Due to limitations with the EoA graphical user interface, for estimates of λ it was necessary to rescale the EoA-produced estimates to represent three full years of operation and monitoring using the sum of these ρ values. For adaptive management triggers associated with λ, it was necessary to scale the annual rate threshold (τ) to represent the level of risk in the moving average estimate of λ.

Evidence of Absence 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 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 50th credible bound, of the posterior distribution 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 enact avoidance measures.

RESULTS

Standardized Carcass Searches

Three hundred forty-seven searches were conducted during the spring monitoring season; a single search was missed due to safety hazards.

Twenty-two bat carcasses and two bird carcasses were found during surveys and incidentally (Appendix A). No federally or state-listed as threatened or endangered species were found during surveys or incidentally. The only two bat species found were the silver-haired bat (20 carcasses; 90.9%) and the eastern red bat (two carcasses; 9.1%).

Statistical Analysis

Bias Trials

Searcher Efficiency Trials

Seventy-eight bat carcasses were placed for SEEF trials on six separate dates; 29 were available for searchers to find on 100-m expanded road and pads and 24 were available for searchers to find on 70-m full plots (Table 3). The best-fit model for SEEF included plot type as covariate, meaning there was significant difference in SEEF between full plots and expanded road and pads (Table 3, Appendix B1).

Table 3. Searcher efficiency results by plot type at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Plot Type	Number Placed	Number Available	Number Found	% Found
100-m expanded road and pad	40	29	23	79.3
70-m full plot	38	24	9	37.5

m = meters.

Carcass Persistence Trials

Fifty carcasses were used to estimate carcass persistence. Twenty-five carcasses were placed on 100-m expanded road and pads and 25 were placed on 70-m full plots. The best-fit model for carcass persistence had no covariates with a Weibull distribution, suggesting there was no significant difference in carcass persistence between plot types or vegetation cover (Appendix B2). The average probability that a carcass persisted through a 3.5-day search interval was 0.68 (90% CI: 0.59–0.77; Figure 5).

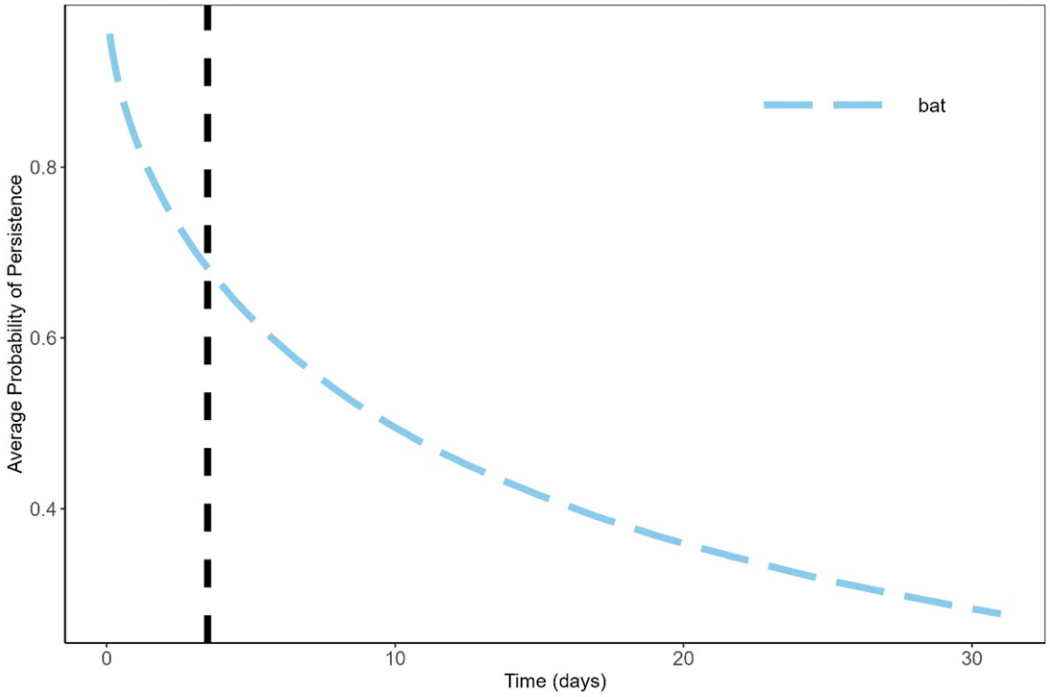

Figure 5. The average probability of persistence, in days, for bat carcasses at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Note: The vertical dashed line indicates the 3.5-day search interval used in this study.

Area Adjustment

One of the 22 bats found during the monitoring season was excluded from modeling the area adjustment for EoA because it was found after the last scheduled search at that turbine (Appendix C1). The TWL area adjustment for bats on 100-m expanded road and pads was 0.36 (90% CI: 0.28–0.43), and the TWL area adjustment for bats on 70-m full plots was 0.97 (90%CI: 0.92–0.99; Table 4, Appendix C2–C3).

Table 4. Truncated weighted maximum likelihood search area adjustment estimates for bats found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Plot Type	Distribution	Parameter 1	Parameter 2	Area Adjustment
100-m expanded road and pad	normal	34.5376	18.6226	0.36
70-m full plot	normal	34.5376	18.6226	0.97

n = 21 bat carcasses

m = meter.

Covered Species Take Estimates

No Covered Species carcasses were found during the study, and no Covered Species have been found to date under the ITP. The annual probability of detection distribution (*g*) achieved for the 2023 study period had a mean of 0.262 (90% CI:0.204–0.313; 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.

Table 5. Annual probabilities of detection (g), Ba, Bb, and ρ for the Hog Creek Wind Farm, Hardin County, Ohio, from 2020–2023.

Year	Ba[1]	Bb[1]	ρ[2]	*g*	90% CI
2020	65.520	274.610	0.70	0.193	0.159–0.229
2021	218.390	575.950	1.00	0.268	0.244–0.293
2022	113.179	536.582	1.00	0.199	0.174–0.225
2023	53.730	151.523	0.106	0.262	0.204–0.313
Short-term Trigger (Last 3 Years)[3]	433.500	1,447.937	NA	0.227	0.211–0.243
Long-term Trigger (Cumulative)	433.500	1,447.937	NA	0.227	0.211–0.243

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 is used to combine the probability of detection distributions across years.
3. For this study, data from the last three full study periods (fall 2020 – spring 2023) were used to evaluate the short-term trigger.

CI = confidence interval; NA = not applicable.

Mean annual take rates based on monitoring from the last three full study periods (fall 2020 – spring 2023) were estimated to be 0.79 (90% CI: 0.00–3.03) Indiana bat per year and 0.79 (90% CI: 0.00–3.03) northern long-eared bat per year. The expected average annual take rates reported in the HCP were 3.3 Indiana bats per year and 1.0 northern long-eared bat per year (Table 6).

Cumulative take under the ITP to-date (2020 – 2023), *M*,* at α = 0.5 (50th credible bound), is estimated to be zero Indiana bats and zero northern long-eared bats. The total take permitted by the ITP is 97 Indiana bats and 30 northern long-eared bats over the 30-year permit term.

Adaptive Management Triggers

Evidence of Absence Short-term Trigger

The short-term trigger assesses the probability that the estimated take rate exceeded the expected take rate, $Pr(\lambda > \tau)$. At a 90% confidence level (α = 0.1), $Pr(\lambda > \tau)$ must be greater than

or equal to 0.90 for the short-term trigger to fire. For Indiana bat, Pr(λ > τ) = 0.04, and northern long-eared bat, Pr(λ > τ) = 0.26 (Table 6). Neither probability meets or exceeds 0.90, indicating the short-term trigger was not met and no adaptive management actions are necessary (Table 6, Figure 6).

Table 6. Probability the estimated take rates exceeded the expected take rates for studies conducted within the rolling average interval at the Hog Creek Wind Farm, Hardin County, Ohio, Incidental Take Permit Years 1–3.5 (2020–2023).

Species	Mean λ (90% Confidence Interval)	Expected Take Rate (τ)	Pr(λ >τ)[1]	Short-Term Trigger Fires at α = 0.1?
Indiana bat	0.79 (0–3.03)	3.3	0.04	No
Northern long-eared bat	0.79 (0–3.03)	1.0	0.26	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 is less than 0.90 (e.g., α = 0.1 for a 1-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.

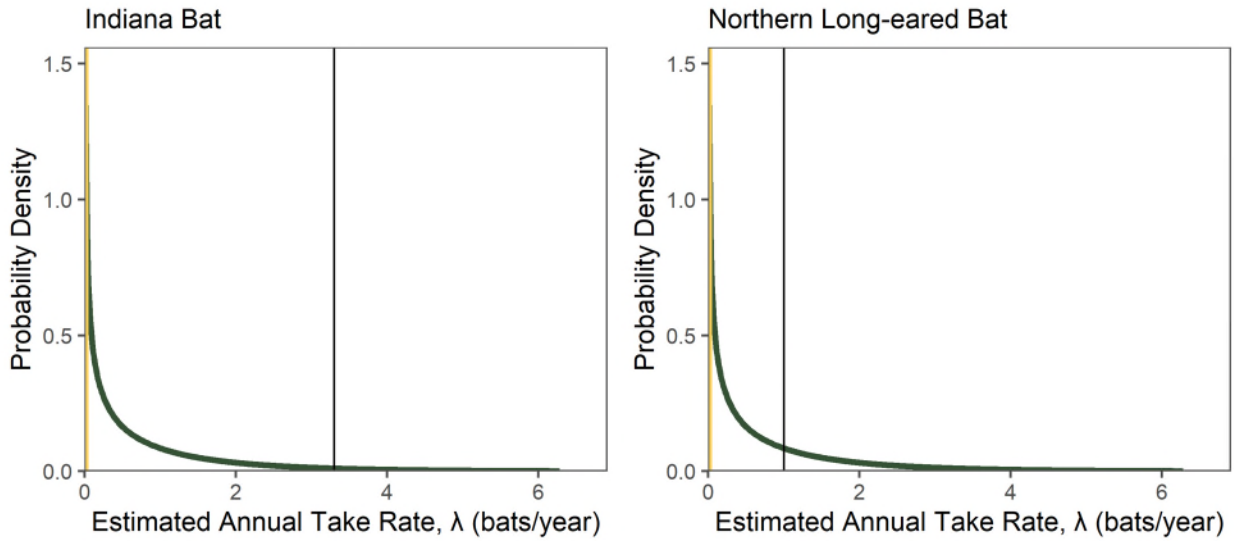

Figure 6. Estimated annual take rates (λ), in bats per year, at the Hog Creek Wind Farm, Hardin County, Ohio, Incidental Take Permit Years 1–3.5 (2020–2023).

Note: The yellow region of the posterior distributions shows the lower 10% quantile of the distributions (yellow region may not be visible when the posterior distribution is skewed heavily toward zero). The black vertical line marks the expected take rate. The short-term trigger evaluates whether the vertical line falls within or to the left of the yellow region of the posterior distributions. For both species, the short-term trigger is not met because the black vertical line (expected take rate) is not within or to the left of the yellow regions. In other words, the probability that estimated take rate is greater than the expected take rate did not exceed 90%.

Evidence of Absence Long-term Trigger

The estimated cumulative take to date, *M** at α = 0.5 (50th credible bound), is below the total permitted take for both Covered Species (Table 7). The long-term trigger was not met and the Project is in compliance 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 Incidental Take Permit (ITP) term to date at the Hog Creek Wind Farm, Hardin County, Ohio, ITP Years 1–3.5 (2020–2023).

Species	Cumulative take (M*)	Permitted take (T)	Long-term trigger fires at α = 0.5?
Indiana bat (50th credible bound)	0	97	No
Northern long-eared bat (50th credible bound)	0	30	No

CONCLUSIONS

The PCM effort completed in 2023 was consistent with the HCP's monitoring requirements and the Project's 2023 study plan. No Covered Species carcasses were found despite a high probability of detection in 2023. Estimates of potential take for the Covered Species were below the levels authorized by the ITP and no adaptive management actions are necessary at this time.

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Appendix A. Carcasses Found during the 2023 Post-construction Monitoring Surveys at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition
Bat Carcasses						
04/10/2023	silver-haired bat	44	27	carcass search	70-m full plot	intact
04/13/2023	silver-haired bat	15	25	carcass search	70-m full plot	intact
04/13/2023	silver-haired bat	68	27	carcass search	70-m full plot	scavenged
04/17/2023	eastern red bat	43	25	carcass search	70-m full plot	scavenged
04/17/2023	silver-haired bat	17	16	carcass search	100-m expanded road and pad	intact
04/17/2023	silver-haired bat	31	17	carcass search	100-m expanded road and pad	intact
04/17/2023	silver-haired bat	30	18	carcass search	70-m full plot	intact
04/18/2023	silver-haired bat	27	11	carcass search	70-m full plot	intact
04/18/2023	silver-haired bat	22	24	carcass search	100-m expanded road and pad	intact
04/24/2023	silver-haired bat	29	17	carcass search	100-m expanded road and pad	intact
04/24/2023	silver-haired bat	56	30	carcass search	70-m full plot	intact
04/26/2023	silver-haired bat	31	14	incidental	100-m expanded road and pad	intact
04/28/2023	silver-haired bat	9	16	incidental	100-m expanded road and pad	intact
05/08/2023	eastern red bat	2	15	carcass search	100-m expanded road and pad	intact
05/08/2023	silver-haired bat	33	18	carcass search	70-m full plot	intact
05/08/2023	silver-haired bat	14	18	carcass search	70-m full plot	intact
05/08/2023	silver-haired bat	60	30	carcass search	70-m full plot	intact
05/08/2023	silver-haired bat	55	30	incidental	70-m full plot	intact
05/08/2023	silver-haired bat	34	30	carcass search	70-m full plot	scavenged
05/11/2023	silver-haired bat	61	25	incidental	70-m full plot	intact
05/11/2023	silver-haired bat	44	25	incidental	n/a	intact
05/11/2023	silver-haired bat	59	30	carcass search	70-m full plot	intact
Bird Carcasses						
04/14/2023	ruby-crowned kinglet	53	10	carcass search	70-m full plot	intact
04/18/2023	golden-crowned kinglet	75	24	carcass search	100-m expanded road and pad	intact

m = meters.

Appendix B. Searcher Efficiency and Carcass Persistence Model Fitting Results at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Appendix B1. Searcher efficiency models for bats from the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023 (n = 53 carcasses).

Covariates	k Value	AICc	Delta AICc
Plot Search Type	k fixed at 0.67	65.56	0*
Vegetation Cover	k fixed at 0.67	65.84	0.28
No Covariates	k fixed at 0.67	73.25	7.69

* Selected model.

K = detection reduction factor; AICc = corrected Akaike Information Criterion; Delta AICc = change in AICc.

Appendix B2. Carcass persistence models with covariates and distributions for bats at the Hog Creek Wind Energy Project, Hardin County, Ohio, from April 1 – May 15, 2023 (n = 50 carcasses).

Location Covariates	Scale Covariates	Distribution	AICc	Delta AICc
No Covariates	No Covariates	Weibull	205.74	0*
No Covariates	No Covariates	loglogistic	206.06	0.32
No Covariates	No Covariates	lognormal	206.09	0.35
Plot Search Type	No Covariates	Weibull	206.78	1.04
Plot Search Type	No Covariates	loglogistic	206.95	1.21
Plot Search Type	No Covariates	lognormal	207.13	1.39
No Covariates	Plot Search Type	Weibull	208.01	2.27
No Covariates	Plot Search Type	loglogistic	208.22	2.48
No Covariates	Plot Search Type	lognormal	208.22	2.48
Vegetation Cover	No Covariates	loglogistic	208.75	3.01
Vegetation Cover	No Covariates	Weibull	209.02	3.28
Vegetation Cover	No Covariates	lognormal	209.08	3.34
Plot Search Type	Plot Search Type	Weibull	209.13	3.39
Plot Search Type	Plot Search Type	loglogistic	209.28	3.54
Plot Search Type	Plot Search Type	lognormal	209.45	3.71
No Covariates	Vegetation Cover	Weibull	209.90	4.16
No Covariates	Vegetation Cover	lognormal	210.53	4.79
No Covariates	Vegetation Cover	loglogistic	210.57	4.83
Vegetation Cover + Plot Search Type	No Covariates	Weibull	211.49	5.75
Vegetation Cover + Plot Search Type	No Covariates	lognormal	211.55	5.81
No Covariates	Vegetation Cover + Plot Search Type	Weibull	212.37	6.63
No Covariates	Vegetation Cover + Plot Search Type	lognormal	213.00	7.26
Vegetation Cover	Vegetation Cover	Weibull	213.23	7.49
Plot Search Type	Vegetation Cover + Plot Search Type	Weibull	213.42	7.68
Vegetation Cover	Vegetation Cover	loglogistic	213.53	7.79
Vegetation Cover	Vegetation Cover	lognormal	213.81	8.07
Vegetation Cover + Plot Search Type	Plot Search Type	Weibull	214.06	8.32
Vegetation Cover + Plot Search Type	Plot Search Type	lognormal	214.11	8.37
Plot Search Type	Vegetation Cover + Plot Search Type	lognormal	214.27	8.53
Vegetation Cover	Vegetation Cover + Plot Search Type	Weibull	215.95	10.21
Vegetation Cover + Plot Search Type	Vegetation Cover	Weibull	215.95	10.21
Vegetation Cover	Vegetation Cover + Plot Search Type	lognormal	216.53	10.79
Vegetation Cover + Plot Search Type	Vegetation Cover	lognormal	216.53	10.79
No Covariates	–	exponential	216.79	11.05
Plot Search Type	–	exponential	217.16	11.42

Appendix B2. Carcass persistence models with covariates and distributions for bats at the Hog Creek Wind Energy Project, Hardin County, Ohio, from April 1 – May 15, 2023 (n = 50 carcasses).

Location Covariates	Scale Covariates	Distribution	AICc	Delta AICc
Vegetation Cover	–	exponential	219.34	13.60
Vegetation Cover + Plot Search Type	–	exponential	221.71	15.97

* Selected model.

AICc = Corrected Akaike Information Criterion; Delta AICc = Change in AICc.

Appendix C. Truncated Weighted Likelihood Area Adjustment Model Fitting Results at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Appendix C1. Number and percent (%) of bat carcasses found and total included in the area adjustment calculation for the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

	Included in Area Adjustment		Outside Search Area*		Outside Study Period*		Total	
Species	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
silver-haired bat	19	90.5	0	–	1	100	20	90.9
eastern red bat	2	9.5	0	–	0	–	2	9.1
Total	**21**	**100**	**0**	**100**	**1**	**–**	**22**	**100**

* Carcasses not included in analysis.

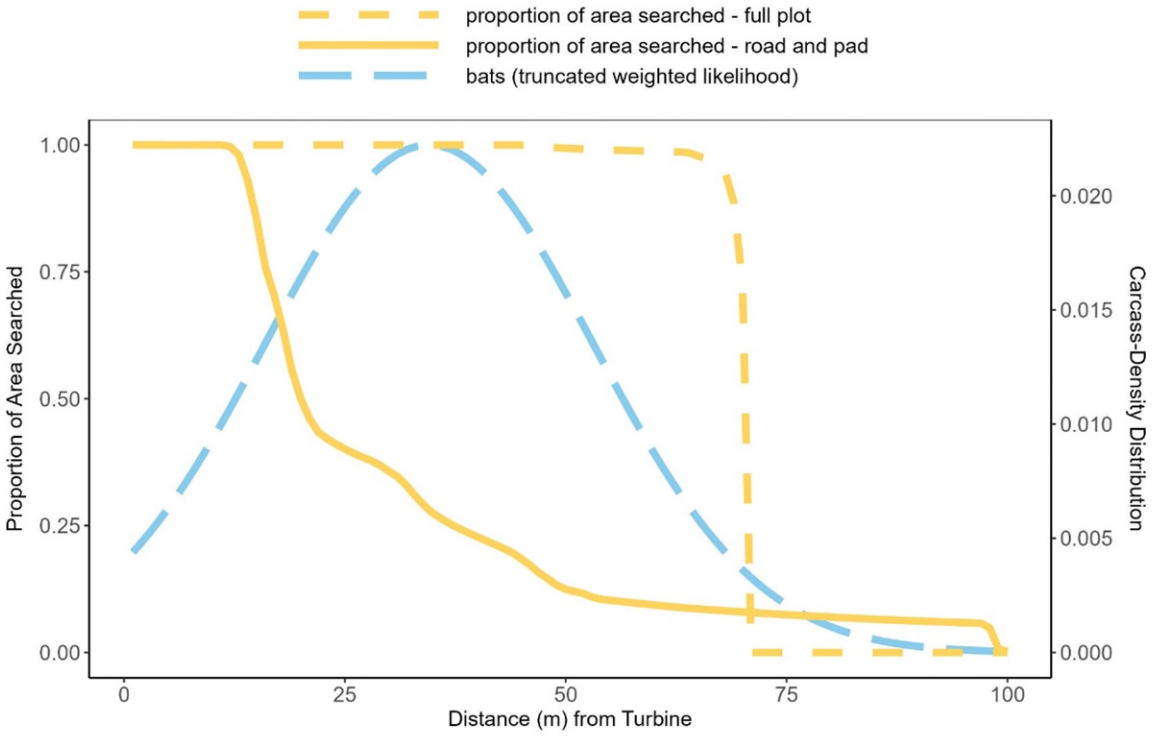
Sums may not equal totals shown due to rounding.

Appendix C2. Search area adjustment models for bats found at turbines at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Distribution	AICc	Delta AICc
normal	575.87	0*
Gompertz	576.12	0.25
Weibull	577.09	1.22
gamma	582.30	6.43

* Selected model.

AICc = Corrected Akaike Information Criterion; Delta AICc = The difference between ranked models.



Appendix C3. Estimated carcass-density distribution for bats and proportion of area searched by distance from turbine at Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Appendix D. Inputs for Single Class and Multiple Class Modules in Evidence of Absence at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

Appendix D1. Inputs needed to run Evidence of Absence: Single Class Module for the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.*

Plot Type	# of Turbines	Search Interval (days)	Average Number of Searches	Spatial Coverage (a)	Temporal Coverage	Searcher Efficiency		Carcass Persistence**	
						Carcasses Available	Carcasses Found	Shape (α)	Scale (β)
100-m expanded road and pad	18	3.5	12	0.36	1	29	23	0.61	7.4
70-m full plot	11	3.5	12	0.97	1	24	9	0.61	7.4

* The detection reduction factor (k) was assumed to equal 0.67 for all strata, per Huso et al. (2017).

** An exponential distribution was assumed for carcass persistence. The 95% upper and lower confidence limits on β were set to 4.46 and 12.27, respectively.

m = meters; NA = not applicable.

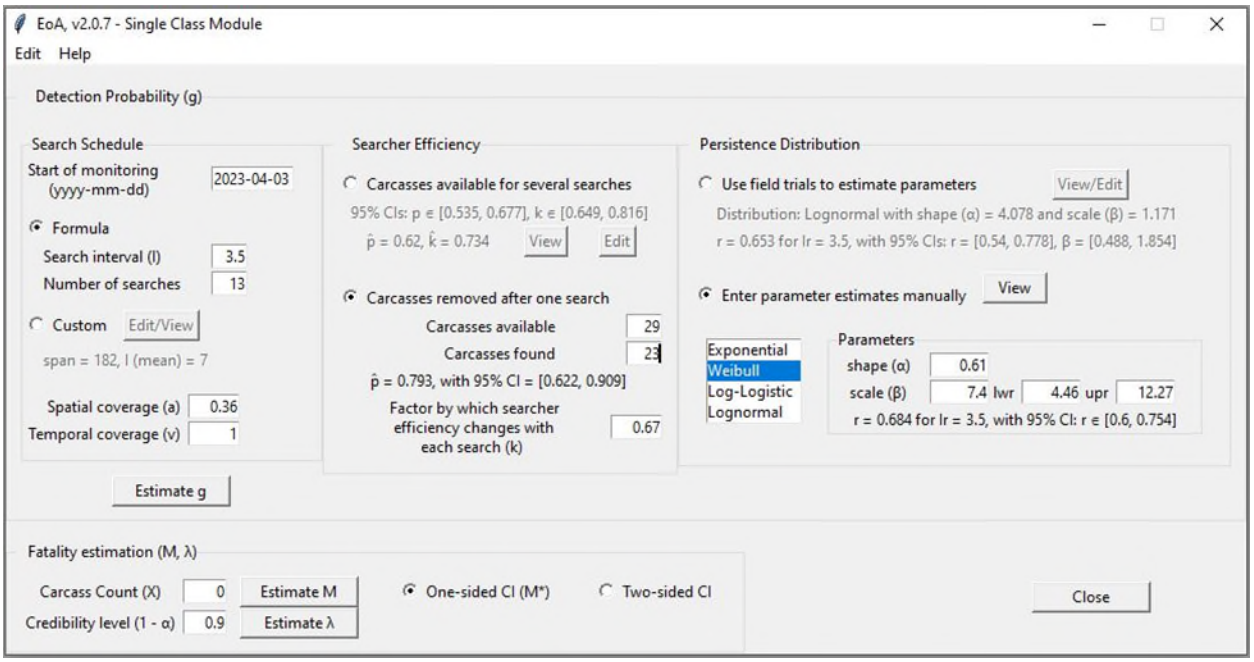
Appendix D2. Inputs needed to run Evidence of Absence model to combine across plot types within the spring study period: Multiple Class Module for the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15, 2023.

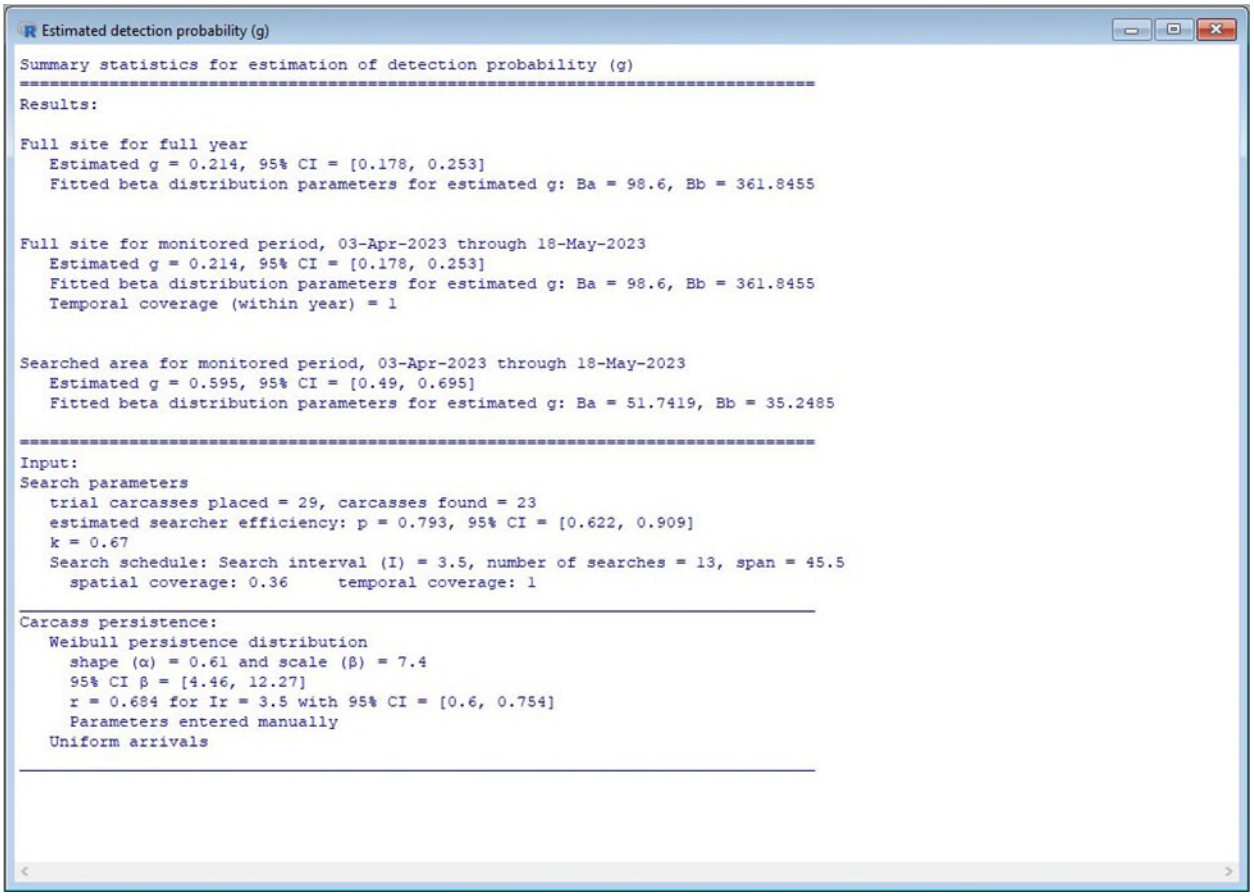
Plot Type	Ba	Bb	Within-Season Sampling Fraction
Unsearched	0.01	1,000.00	0.03
100-m expanded road and pad	104.05	387.95	0.60
70-m full plot	13.51	25.75	0.37

m = meters.

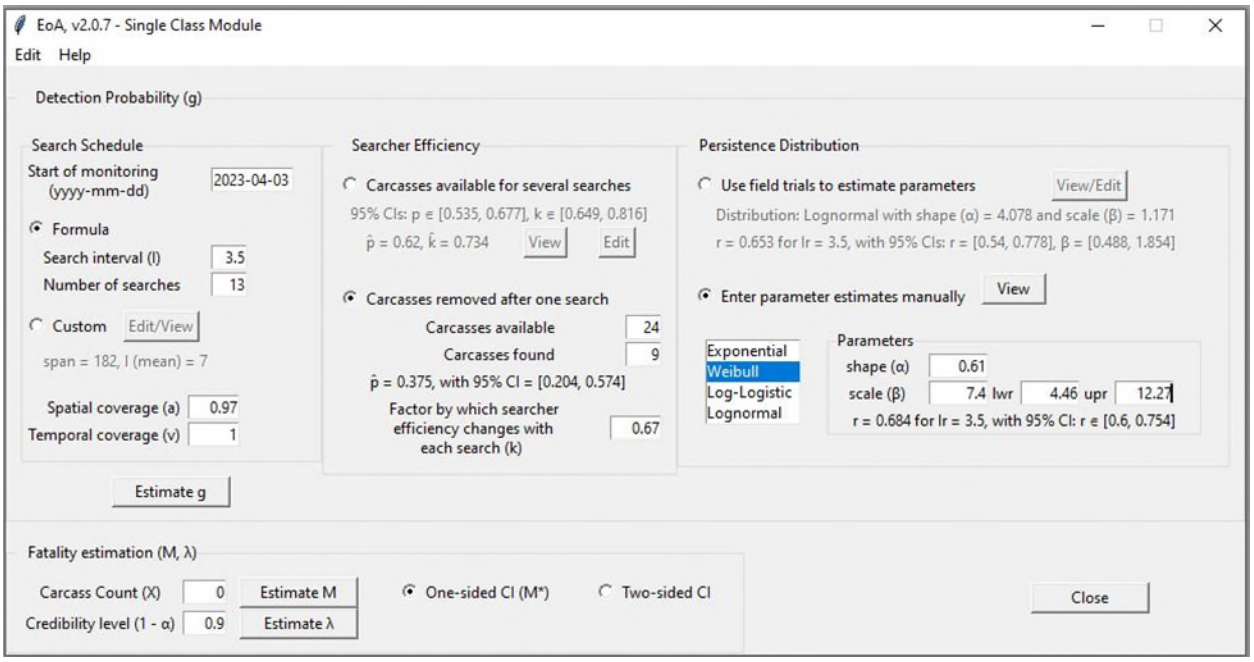
Appendix D3. Inputs needed to run Evidence of Absence model to combine across years: Multiple Years Module for the Hog Creek Wind Farm, Hardin County, Ohio, from 2020–2023.

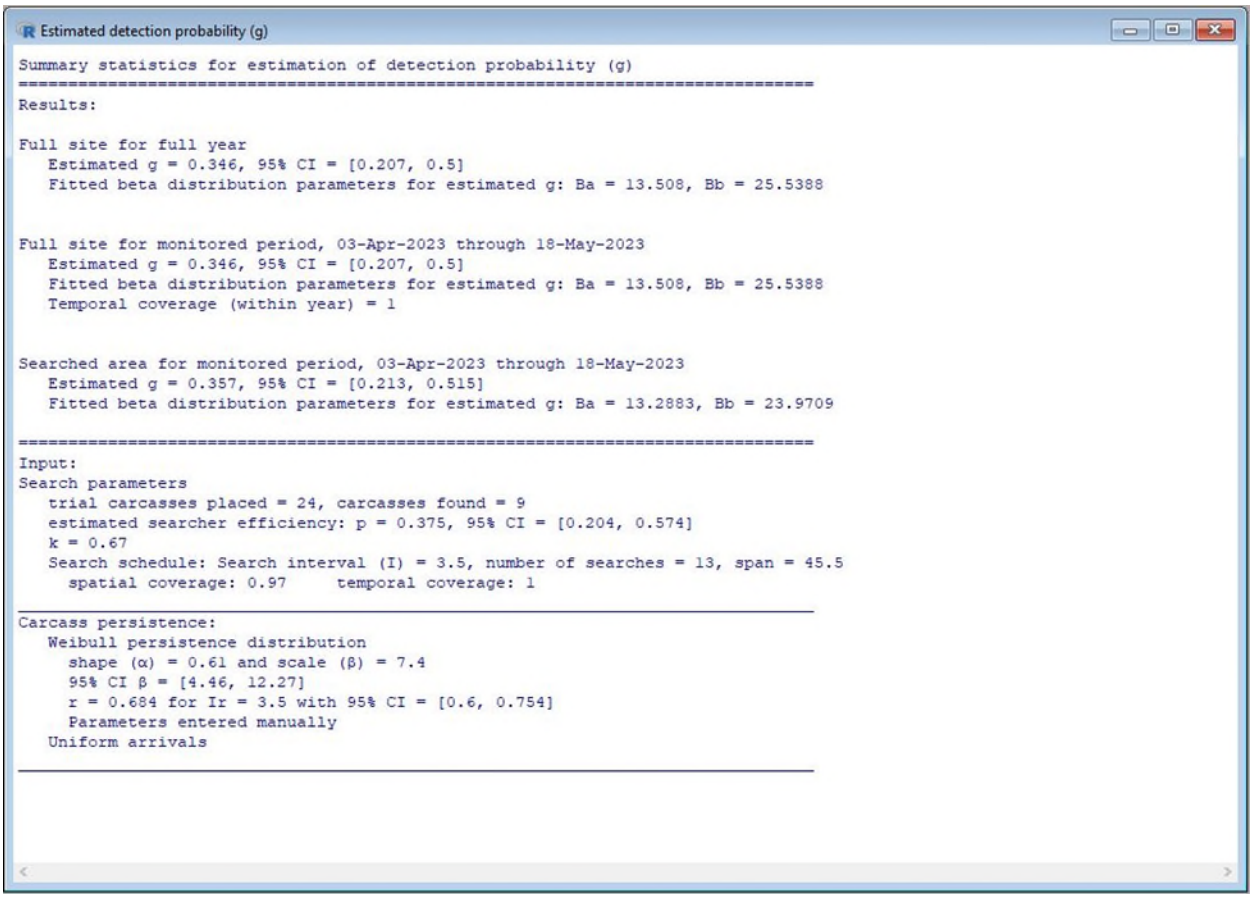
Year	Ba	Bb	Weights (ρ)
2020	65.5200	274.6100	0.70
2021	218.3900	575.9500	1.00
2022	133.1790	536.5820	1.00
2023	53.7298	151.5229	0.106



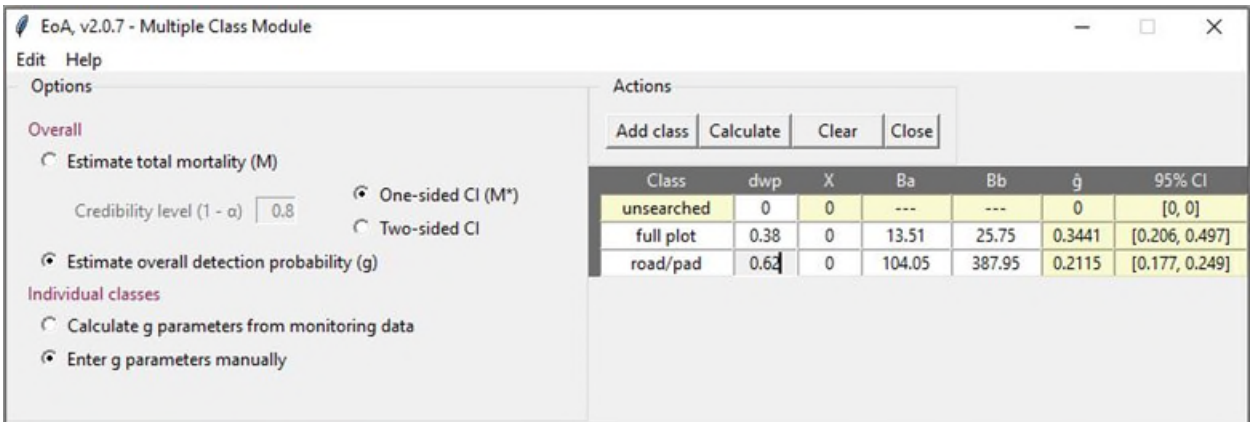


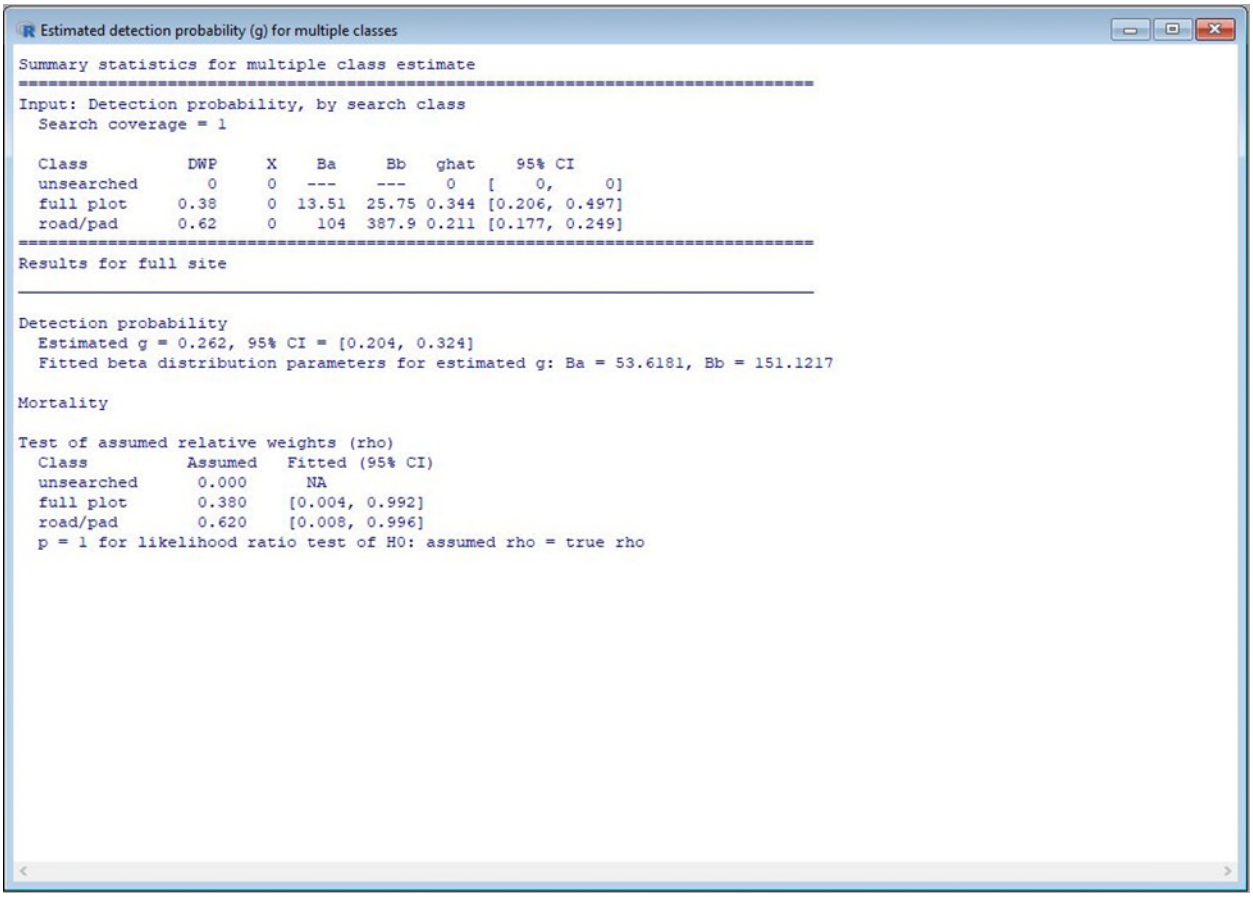
Appendix D4. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for spring 2023, 100-meter expanded road and pad searches at 18 turbines, searched at a 3.5-day interval.



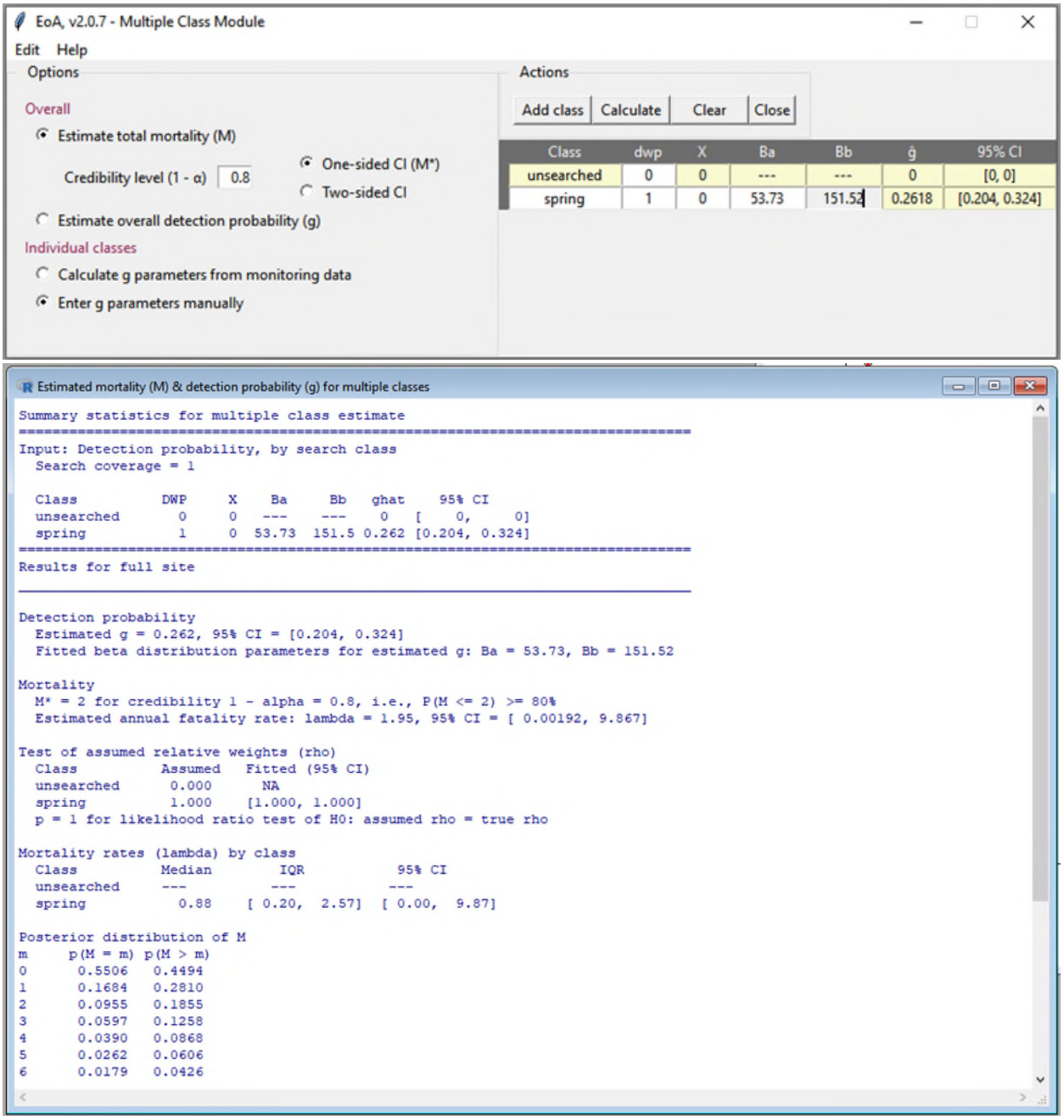


Appendix D5. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for spring 2023, 70-meter full plot searches at 11 turbines, searched at a 3.5-day interval.

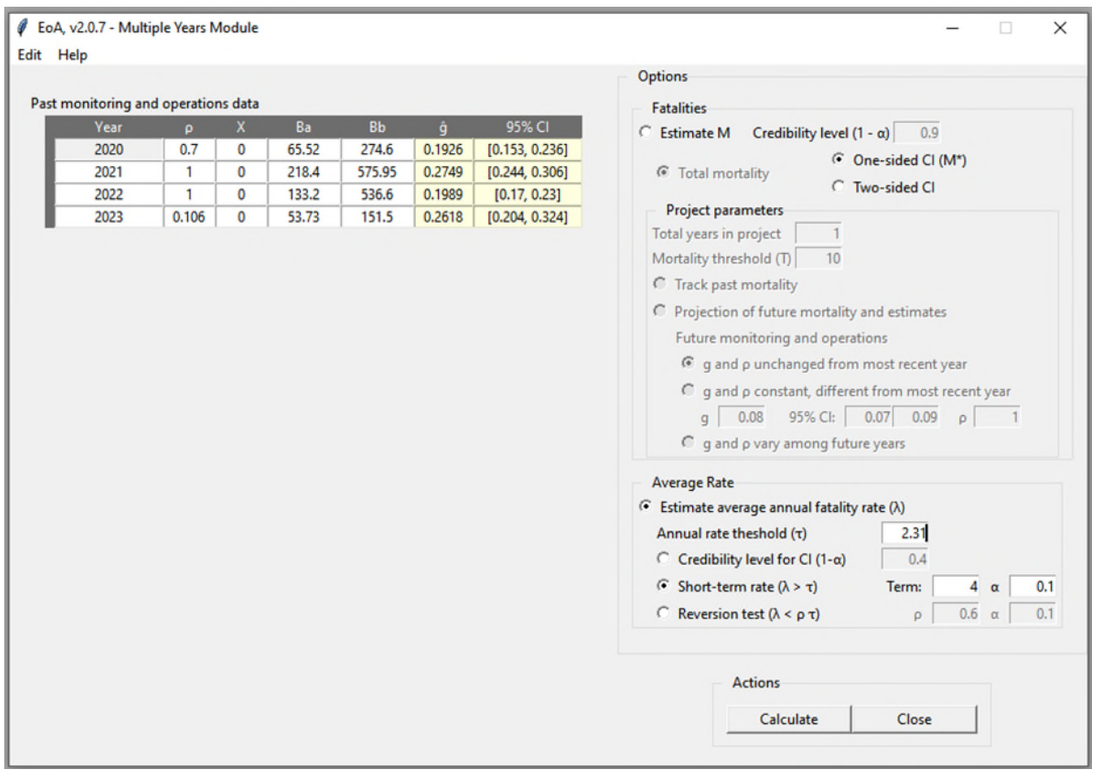


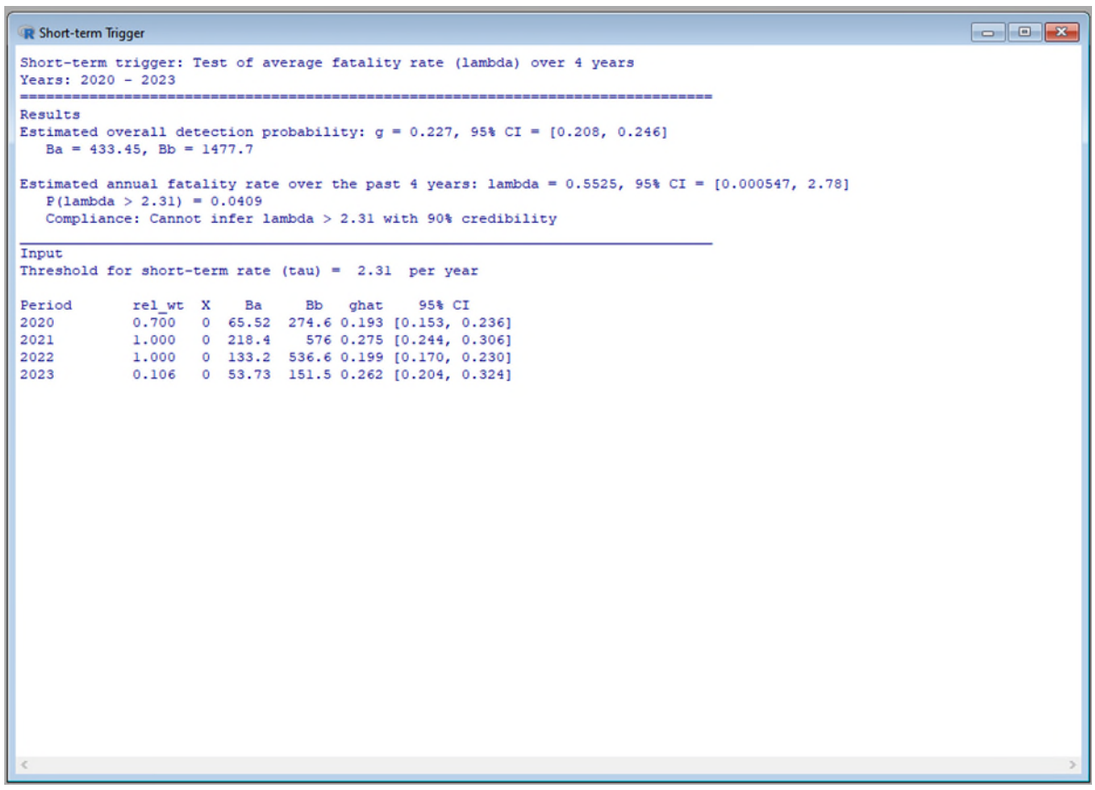


Appendix D6. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Multiple Class Module inputs for spring 2023 stratified by plot type, searches at 29 turbines, searched at a 3.5-day interval.



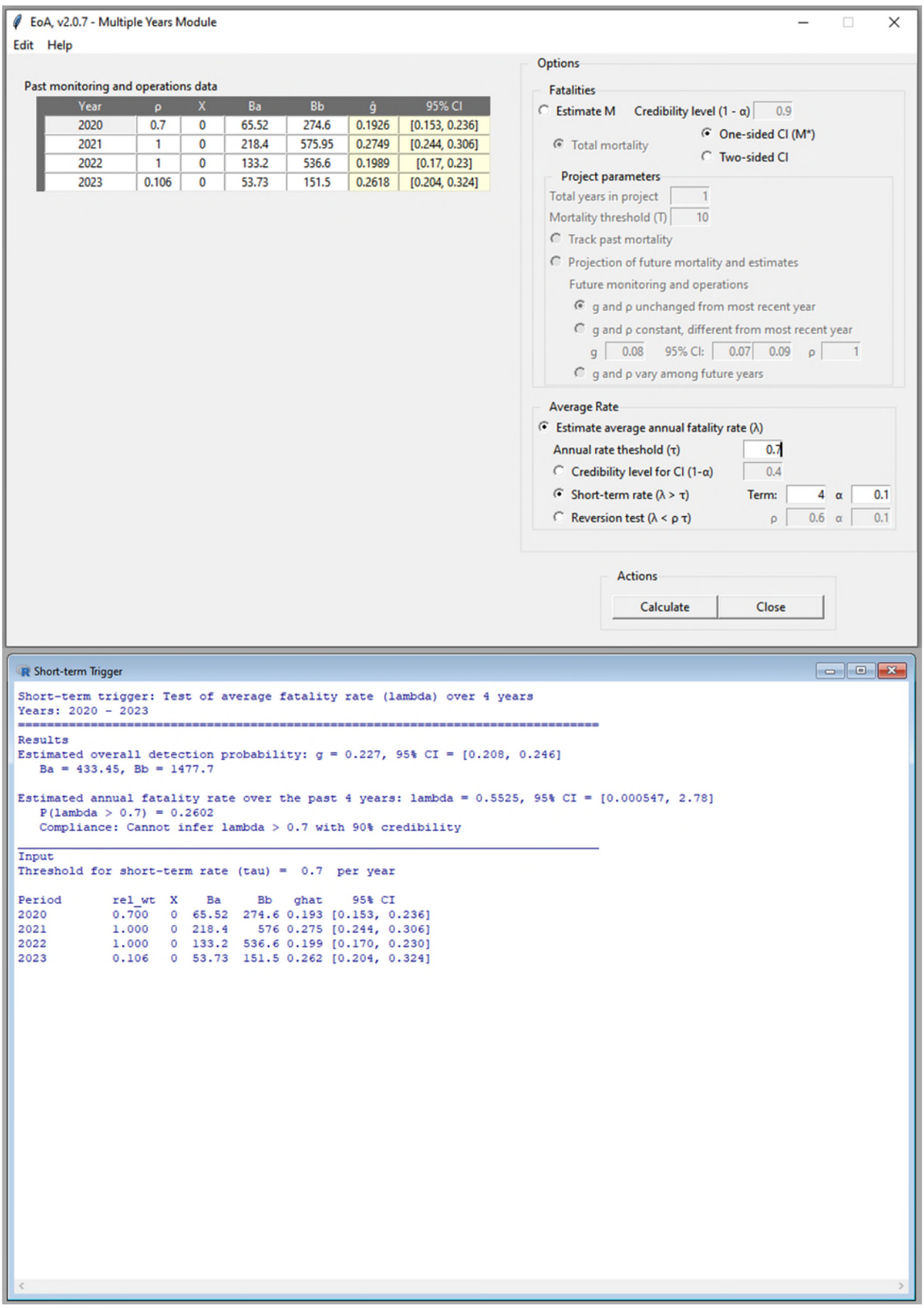
Appendix D7. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Multiple Class Module inputs for spring 2023, searches at 29 turbines, searched at a 3.5-day interval.





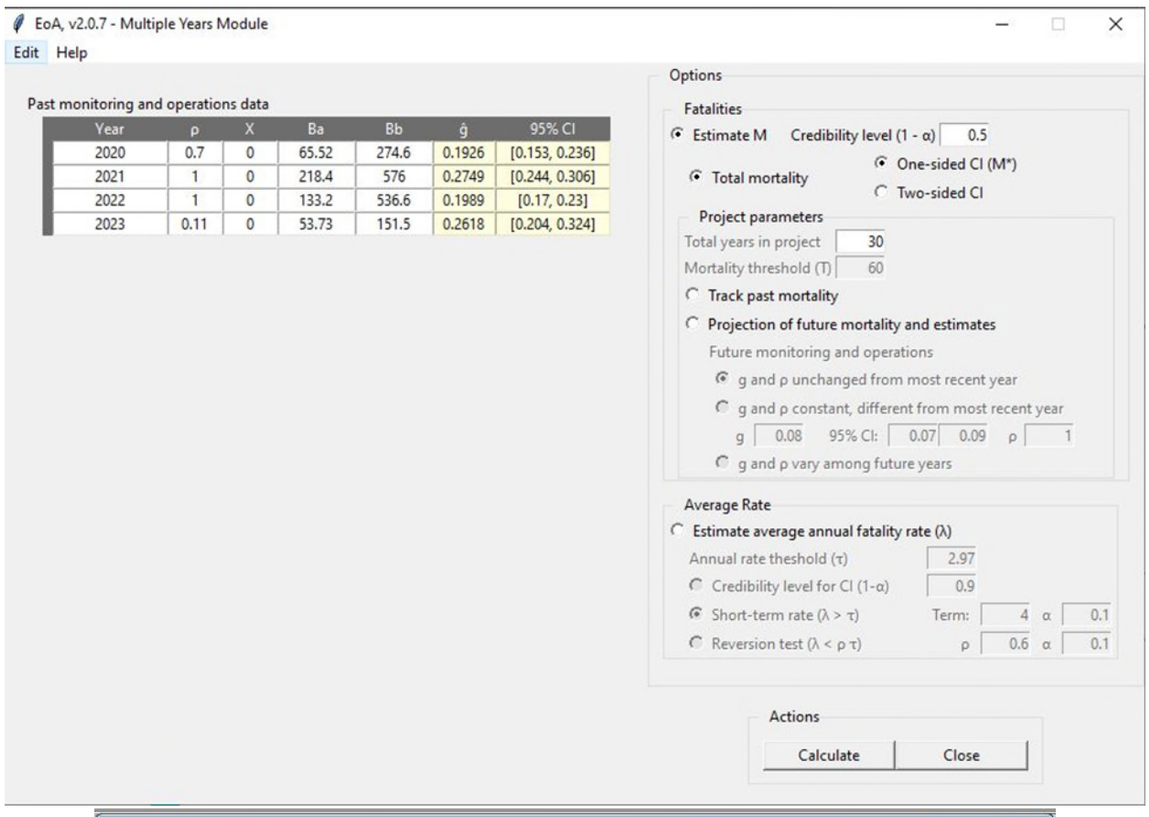
Appendix D8. Screen shot of Evidence of Absence (v2.0.7) graphical user interface (EoA GUI), Multiple Years Module for estimation of Indiana bat rolling average detection probability and short-term adaptive management trigger test. Inputs are based on values reported in the main text.

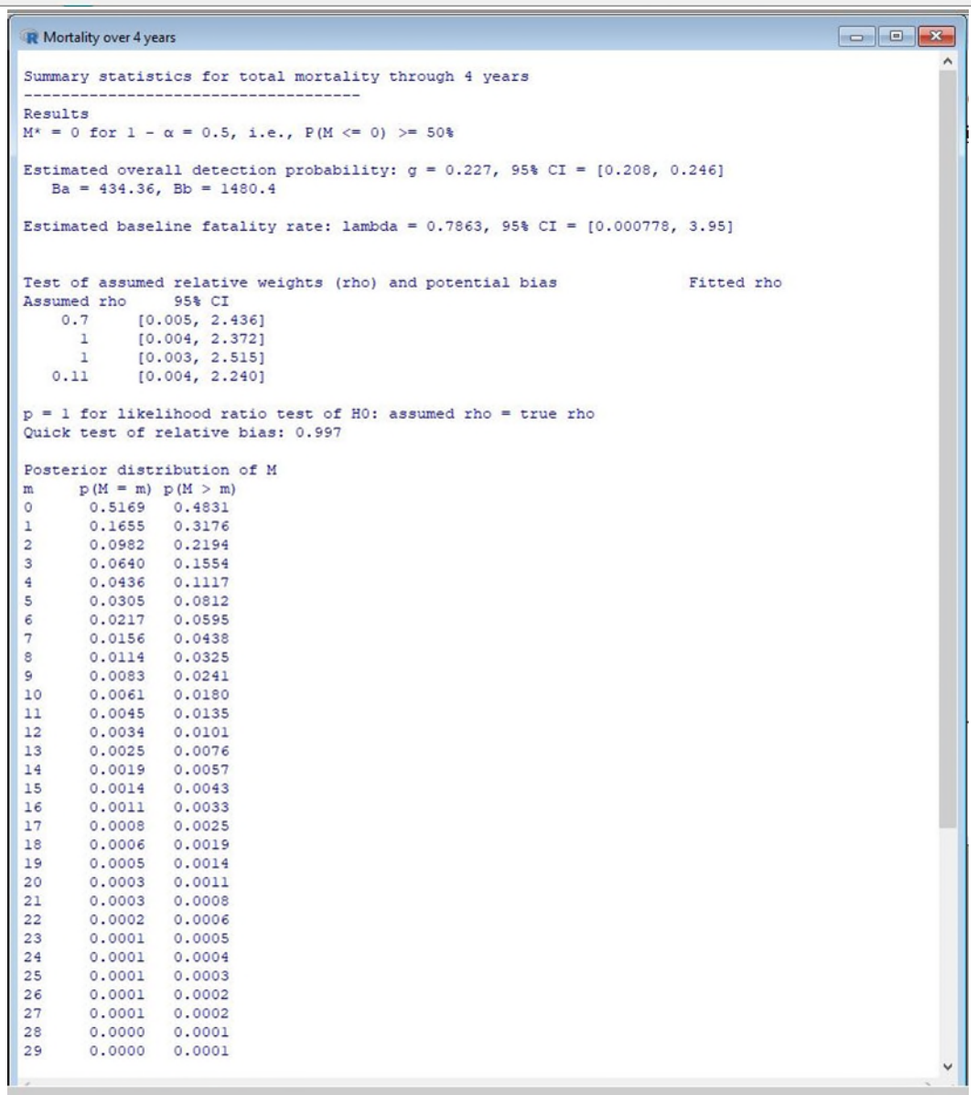
Note that although the weight (ρ) column of the Multiple Years Module sums to 2.8, the EoA GUI produces a "year-adjusted λ" by calculating the average λ over the number of input rows (years) in the multi-year module of the GUI. Because the ρ values associated with each year in the GUI are scaled so that a "ρ" of 1.0 is equivalent to a typical operations year for the wind farm (but 2020 and 2023 were only surveyed for portions of the year), we would like to calculate the "ρ-adjusted λ" but the GUI does not accommodate that calculation. Therefore, the "ρ-adjusted λ", 0.79, is equivalent to the "year-adjusted λ" (0.55 as seen in the output above) divided by the sum of ρ (2.806) multiplied by the number of years (4).



Appendix D9. Screen shot of Evidence of Absence (v2.0.7) graphical user interface (EoA GUI), Multiple Years Module for northern long-eared bat rolling average detection probability and short-term adaptive management trigger test. Inputs are based on values reported in the main text.

Note: although the weight (ρ) column of the Multiple Years Module sums to 2.8, the EoA GUI produces a "year-adjusted λ" by calculating the average λ over the number of input rows (years) in the multi-year module of the GUI. Because the ρ values associated with each year in the GUI are scaled so that a "ρ" of 1.0 is equivalent to a typical operations year for the wind farm (but 2020 and 2023 were only surveyed for portions of the year), we would like to calculate the "ρ-adjusted λ" but the GUI does not accommodate that calculation. Therefore, the "ρ-adjusted λ", 0.79, is equivalent to the "year-adjusted λ" (0.55) as seen in the output above) divided by the sum of ρ (2.8) multiplied by the number of years (4).





Appendix D10. Screen shot of Evidence of Absence (v2.0.7) graphical user interface (EoA GUI), Multiple Years Module for Indiana bat and northern long-eared bat ITP term-to-date detection probability and cumulative take estimate (M*). Inputs are based on values reported in the main text.