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

Year 3 Draft Report

April 1 – May 15 and August 1 – October 15, 2022

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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 study conducted in 2022, 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 during spring and summer and under increased cut-in speeds during fall migration per the Project's HCP.

Post-construction fatality monitoring was completed in accordance with the study plan, which was approved by the US Fish and Wildlife Service on March 18, 2022. The study plan was designed to achieve a 25% probability of detecting a single bat carcass (*g* of 0.25) for the 30 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 three plot types: 70-m cleared plots, 70-m uncleared plots, and 100-m road and pads. Searches 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 occuring 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. One hundred seventeen bat carcasses were found during the study. The most commonly found bat species were eastern red bat (38.5%), silver-haired bat (31.6%), big brown bat (19.7%), and hoary bat (10.3%). Species composition recorded at the Project was similar to previous studies at the Project and other wind facilities in Ohio and Indiana. Forty-seven bird carcasses were recorded; no federally or state-listed birds were found.

The *g* was 0.20 (90% confidence interval: 0.17–0.22). Based on the data collected to date (2020–2022), the EoA model estimated the mean annual fatality rates were 0.83 Indiana bats and 0.83 northern long-eared bats. The probability that the annual take rate exceeded the expected annual take rate was 0.05 for Indiana bat and 0.27 for northern long-eared bat. The cumulative take estimates through 2022 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.

STUDY PARTICIPANTS

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REPORT REFERENCE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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 endangered Indiana bat (*Myotis sodalis*) and the federally listed endangered 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 season (August 15 – October 15, 2020) and one full season (April 1 – May 15 and August 1 – October 15, 2021) of monitoring prior. This report presents the results of the third consecutive survey period of compliance monitoring conducted under the ITP from April 1 – May 15 and August 1 – October 15, 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) 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 that covers approximately 2.7% of the site. All other land cover types collectively make up less than 1% of the total land cover (Figure 1; National Land Cover Database 2019).

The Project became fully operational in 2017, and consists of thirty 2.2-megawatt (MW) Vestas V110 wind turbines that have a 95 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 and fall migration periods to minimize impacts to the Covered Species (Table 1).

[1] The northern long-eared bat was listed as threatened when the ITP was received. Its status will change to endangered as of March 31, 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. 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.

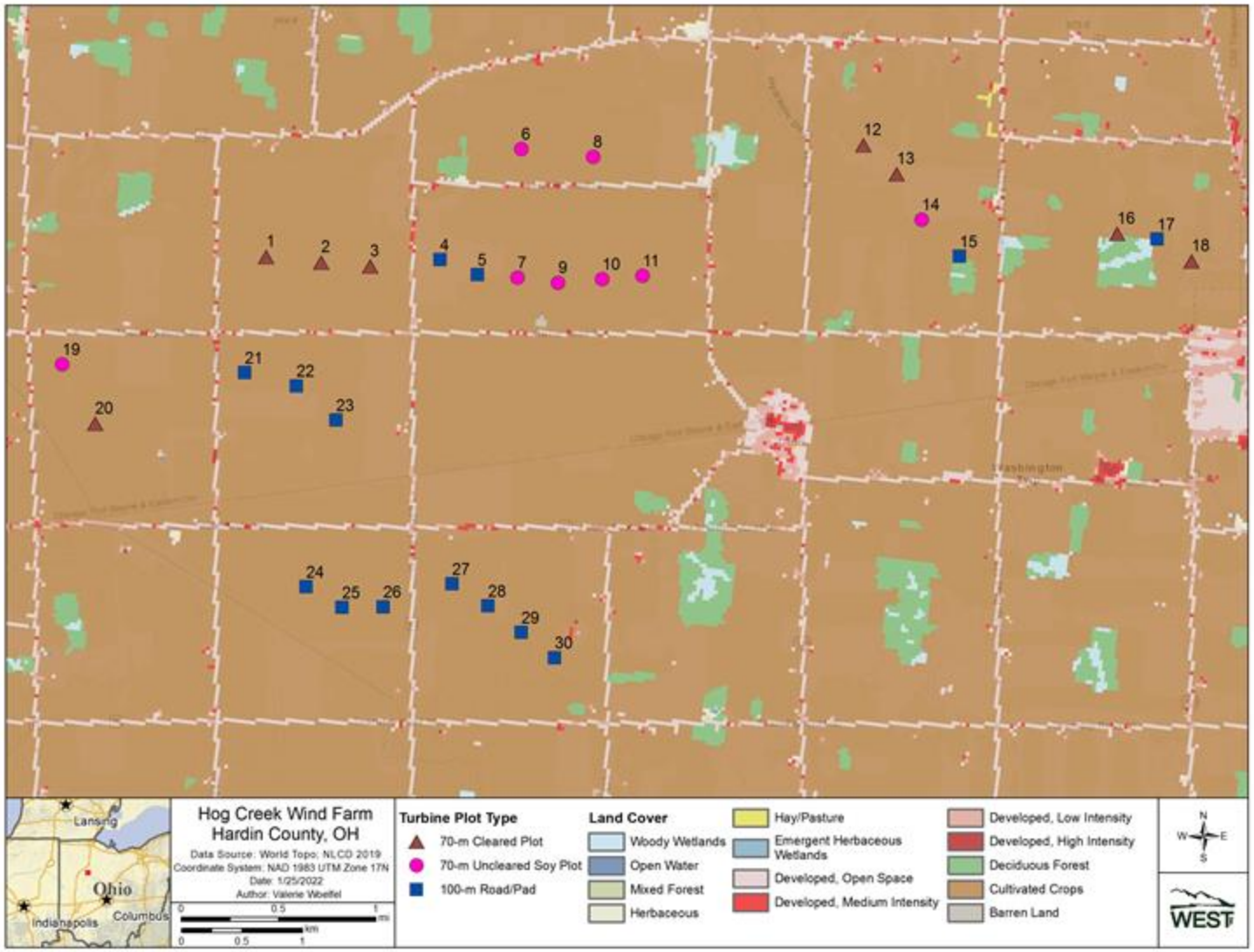

Figure 1. Turbine locations, fall turbine plot types, and surrounding land cover at the Hog Creek Wind Farm, Hardin County, Ohio. During spring monitoring, all 30 turbines were searched as 100-meter road and pads.

METHODS

WEST used Project-specific data from previous post-construction monitoring studies at the Project to develop a study plan that targeted a *g* of 0.25 (Matteson et al. 2022) to meet the monitoring commitments in the HCP. WEST submitted a study plan to EDPR on March 3, 2022, and received approval from the USFWS on March 18, 2022 (K. Lott, USFWS, pers. comm.).

Standardized Carcass Searches

Number of Turbines Sampled, Search Frequency, and Plot Size

Technicians and dog-handler teams conducted standardized carcass searches from April 1 – May 15 and August 1 – October 15, 2022. Search effort varied by season (Table 2, Figure 1), and was designed to maximize effort when the greatest number of Covered Species were expected to occur.

A technician searched the gravel road and pad areas (road and pads) under all 30 turbines to a distance of 100 m from the turbine, every week during the spring (Table 2).

Logistical constraints and land access issues delayed mowing of cleared plots for the fall season. All corn *(Zea mays)* and other vegetation (e.g., grasses) was to be cut within the 70-m (260-ft) cleared plots prior to the start of surveys, and, thereafter, maintained as needed to keep vegetation heights low and preserve optimum visibility in the plots. A cross pattern was to be mowed into the soy (*Glycine max*) crop within the 70-m uncleared plots prior to the start of surveys to aid in detection of bat carcasses by the detection dog teams. Initial vegetation clearing began by mowing on August 25, 2022. Prior to this date, corn stalks were more than 2.0 m (6.6 ft) in height and soy fields were 0.5 m (1.6 ft) in height. Furthermore, as a result of weather-related delays, regular vegetation maintenance did not occur at all plots every two weeks as expected due to standing water and muddy conditions limiting access to the fields.

Thus, for the purposes of analysis, the fall season was split into three periods based on the timing of mowing and the number of turbines that could be searched as 70-m plots: Fall 1 occured prior to mowing (August 1 – 25, 2022) with searches at 25 turbines; Fall 2 occured from August 26 – September 14, 2022 with searches at 29 turbines; and Fall 3 occured after a second round of mowing from September 15 – October 15, 2022 with searches at all 30 turbines. Due to delays in mowing, the final number of road and pads, 70-m cleared plots, and 70-m uncleared plots differed from the approved study plan, which specified 16 100-m road and pads, 8 70-m cleared plots, and 6 70-m uncleared plots. Three of the planned 70-m uncleared plots were changed to 70-m cleared plots to compensate for some of the reduced searches early in the fall season, and one of the planned 70-m uncleared plots became a 100-m road and pad plot due to land access issues.

Table 2. Search effort by season and plot type at Hog Creek Wind Farm, Hardin County, Ohio.

Season	Plot Type	Search Interval	Number of Turbines	Search Team
Spring (April 1 – May 15)	100-m road and pad	7.0 days	30	Technician
Fall (August 1 – October 15)	100-m road and pad	7.0 days	17	Technician
	70-m cleared plot	3.5 days	11	Dog-handler
	70-m uncleared plot	3.5 days	2	Dog-handler

m = meters.

All turbines were searched once or twice per week during the fall (Table 2). A technician searched 17 turbines weekly as road and pads to a distance of 100 m from the turbine (Figure 2). Dog-handler teams searched 11 turbines where crops were regularly mowed within a 70-m radius of the turbine tower (70-m cleared plots; Figure 3) and two turbines as uncleared plots with a 70-m radius around the turbine tower (70-m uncleared plots; Figure 4).

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 dog. 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.

Road and Pad Searches – Technician 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 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 2. Representative photo of conditions in a 100-meter road and pad plot at the Hog Creek Wind Farm, Hardin County, Ohio.

Figure 3. Representative photo of vegetation conditions in a 70-meter cleared plot at the Hog Creek Wind Farm, Hardin County, Ohio.

Figure 4. Representative photo of vegetation conditions in a 70-meter uncleared plot at the Hog Creek Wind Farm, Hardin County, Ohio.

Plot Searches – Dog-handler Team

Dog-handler teams searched 70-m cleared and 70-m uncleared plots for bat carcasses. Prior to each search, handlers determined the survey start points and the number of transects needed to cover the plot after taking into account wind speed and direction, as well as crop row direction and density (when applicable). Handlers oriented the detection dog to start searches perpendicular to the wind to maximize scent detection. Both windspeed 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 bird or bat carcass.

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 10 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 2-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. Breeds used at the Project as detection dogs included two golden Labrador retrievers and a chocolate Labrador retriever.

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 (TE234121-9), 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 any state- or federally listed species, but none were identified during the searches. A permitted bat biologist (TE62046D-0) 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 October 19, 2022.

Tissue samples were collected from heavily scavenged or decomposed carcasses that could not be positively identified and had potential to be a Covered Species. WEST submitted these samples to a USFWS-approved laboratory, the East Stroudsburg University Willdife Genetics Institute, for genetic identification.

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*), 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. One hundred twenty-five carcasses were placed across all season and plot types to account for differences in search conditions by plot type and season.

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 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 walked

in a meandering path and dropped trials for detection dogs the day prior to the next search to allow time for the scent to pool and disperse prior to scheduled searches. 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. Technicians did not know when the trial administrator placed carcasses.

Technicians and dog-handler teams 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. Following searches, any carcasses that were not detected were checked to confirm availability. Forty-five trial carcases were left in place to be 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 planned 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 on a plot during the same trial period to avoid potential over-seeding and attracting scavengers. Due to the limited number of uncleared plots (n = 2) and the need to avoid over-seeding those plots, we considered cleared and uncleared plots as one plot type for estimating carcass persistence in the fall survey period.

Technicians monitored the 45 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, 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 cleared and uncleared plots to determine when carcasses were removed, while technicians determined the status of carcasses placed on 100-m road and pads.

Search Area Mapping

The boundaries of 100-m road and pads had been mapped using sub-meter Global Positioning Sytstem units in prior monitoring years. Technicians recorded the boundaries of 70-m cleared plots using an Eos sub-meter Global Positioning System unit. Unsearchable areas within plot boundaries were also mapped. The 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. A 72-m (236-ft) radius projection was applied to 70-m uncleared plots. The additional 2.0 m (6.6 ft) was added to the radius to account for the width of the turbine tower.

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, 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, we modeled searcher efficiency using logistic regression. In these analyses, searcher efficiency data from Fall 1, Fall 2, and Fall 3 were treated as a single fall season. 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 that was missed on the first search would never be found on subsequent searches. A *k* of one implies searcher efficiency remained constant no matter how many times a carcass 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, loglogistic, lognormal, and Weibull distributions (Kalbfleisch and Prentice 2002, Dalthorp et al. 2018). As with searcher efficiency, carcass persistence models were estimated separately by search team (i.e.,

plots searched by technicians vs. plots searched by dog-handler teams) to account for different modes of detection. Season was included as a potential covariate for the technician model, and plot type was included as a potential covariate for the dog-handler model. In these analyses, carcass persistence data from Fall 1, Fall 2, and Fall 3 were treated as a single fall season. 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. Separate area adjustment estimates were calculated for Fall 1, Fall 2, and Fall 3. 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 [2016] and Yee [2010]). 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 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* was estimated using the bias corrections for searcher efficiency, carcass persistence, and area searched, as well as the assumed seasonality of risk for the Covered Species, which per the

HCP was 11% in the spring and 89% in the fall. The seasonal risk is used to weight the contributions of detection probability from different seasons in the overall *g* estimate. Differences in the level of turbine operations within (e.g., turbines down for maintenance for extended periods within a season) and across seasons (e.g., reduced summer risk) were also considered and adjustments for variable turbine operations were not needed for this analysis due to a lack of significant turbine downtime during the study period.

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 cleared plots, 70-m uncleared plots, and 100-m 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. 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]. For this study, the mowing delays (and thus unplanned changes in searchable area) at the Project were accounted for by splitting the fall monitoring season into three fall seasons: Fall 1 occured prior to mowing (August 1 – August 25) with five turbines not being searched; Fall 2 occurred after the first round of mowing (August 26 – September 14) with one turbine not being searched; and Fall 3 occurred after the second round of mowing (September 15 – October 15) with all turbines being searched. The fall sub-season arrival proportions were scaled based on the number of visits in each sub-season divided by the total number of visits in the whole fall season (Table 3). The proportion of tubines searched for each sub-season and plot type (100-m road and pad, 70-m cleared plot, and 70-m uncleared plot) was also calculated. The product of the arrival proportions and the proportion of turbines searched defined the weights for combining the beta distribution parameters across seasons and sub-seasons.

Table 3. Rescaled arrival proportions for the fall season at Hog Creek Wind Farm, Hardin County, Ohio, from August 1 – October 15, 2022.

Season	Rescaled Arrival Proportion
Fall 1 (August 1 – August 25)	0.254
Fall 2 (August 26 – September 14)	0.254
Fall 3 (September 15 – October 15)	0.381

Furthermore, the Multiple Years Module was used to estimate the site-wide, cumulative detection probability for the three monitoring periods in 2020–2022. 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

[1] 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.

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.

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 post-construction monitoring 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 median cumulative take estimate (*M**) remains within the permitted limit over the ITP term. Data from three monitoring periods were used in this analysis (2020, 2021, and 2022) along with the values of ρ listed above (0.70, 1.0, 1.0, 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

Six hundred thirty-four searches were conducted during the spring and fall monitoring seasons; 40 searches (6%) were missed due to delays in mowing cleared plots and/or safety hazards.

No federally or state-listed bat species were found. One hundred seventeen bat carcasses and 47 bird carcasses were found during surveys and incidentally (Appendix A). The most commonly found bat species were eastern red bat (45 carcasses; 38.5%) and silver-haired bat (37 carcasses; 31.6%), followed by big brown bat (23 carcasses; 19.7%) and hoary bat (12 carcasses; 10.3%). Four heavily scavenged bats (e.g., wing membrane only, bones, or partial carcasses) were sent off for identification via deoxyribonucleic acid (DNA) analysis; one was identified as a big brown bat and three were identified as silver-haired bats.

Statistical Analysis

Bias Trials

Searcher Efficiency Trials

One hundred twenty-five bats were placed for searcher efficiency trials on 13 separate dates, and 87 bats were available for searchers to find across all plot types. The best-fit model for searcher efficiency on 100-m road and pads did not support the inclusion of season as a covariate, meaning there was not a statistically meaningful difference between searcher efficiency rates across seasons (Table 4, Appendix B1). The best-fit model for searcher efficiency on 70-m plots did not support the inclusion of plot type, meaning there was not a statistically meaningful difference between searcher efficiency on uncleared and cleared plots (Table 4, Appendix B2).

Table 4. Searcher efficiency results by plot type at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Plot Type	Number Placed	Number Available	Number Found	% Found
100-m Road and Pad	69	53	50	94.3
70-m Cleared and Uncleared	56	34	27	79.4

m = meters.

Carcass Persistence Trials

Twenty-eight carcasses were placed to estimate carcass persistence on 100-m road and pads; however, one carcass was removed from the analysis due to technician error during the monitoring period. The best-fit model for carcass persistence on 100-m road and pads included season as a covariate with a Weibull distribution, which suggests that carcass persistence varied by season (Appendix B3). Seventeen carcasses were placed to estimate carcass persistence on 70-m cleared and uncleared plots. The best-fit model for carcass persistence had no covariates with a Weibull distribution, which suggests carcass persistence rates did not vary by plot type (Appendix B4). For road and pad plots, the median probability that a carcass persisted through a 7-day search interval was 0.64 (90% CI: 0.49–0.78) in spring and 0.32 (90% CI: 0.18–0.49) in fall (Table 5, Figure 5). On 70-m cleared and uncleared plots, the median probability that a carcass persisted through a 3.5-day search interval in fall was 0.55 (90% CI: 0.40–0.72; Table 5, Figure 6).

Table 5. Median carcass persistence probability through the search interval at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Season	Plot Type	Searcher Type	Search Interval (days)	Median Carcass Persistence Probability	90% Confidence Interval
Spring	100-m Road and Pad	Technician	7.0	0.64	0.49–0.78
Fall	100-m Road and Pad	Technician	7.0	0.32	0.18–0.49
	70-m Cleared and Uncleared	Dog-Handler	3.5	0.55	0.40–0.72

m = meters.

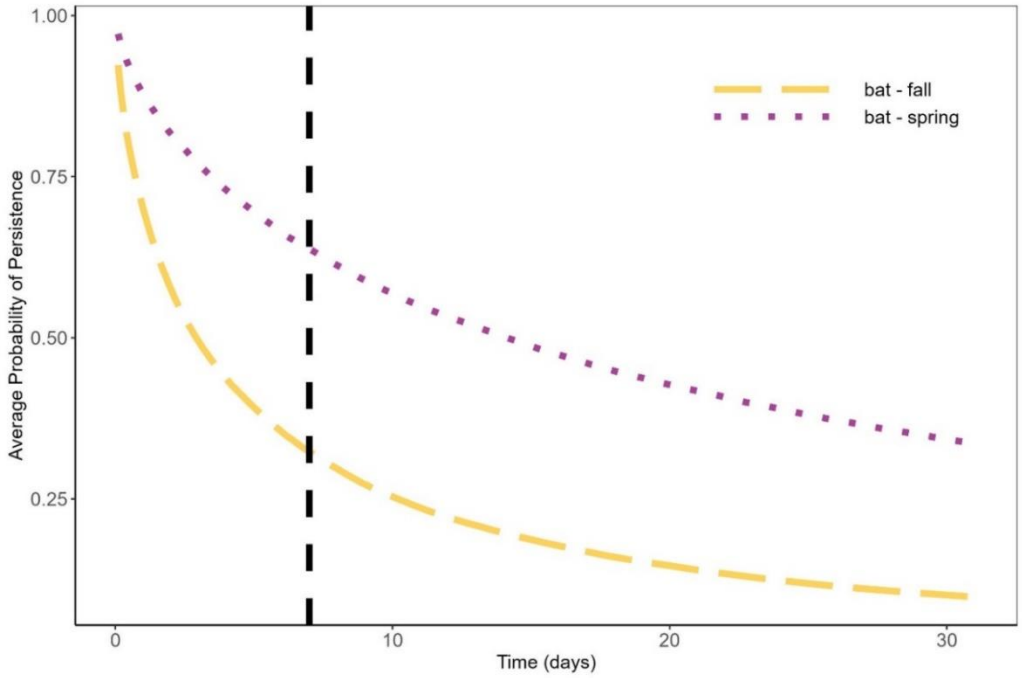

Figure 5. The average probability of persistence, in days, for bat carcasses on 100-meter road and pads at Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Note: The vertical dashed line indicates the 7-day search interval used in this study.

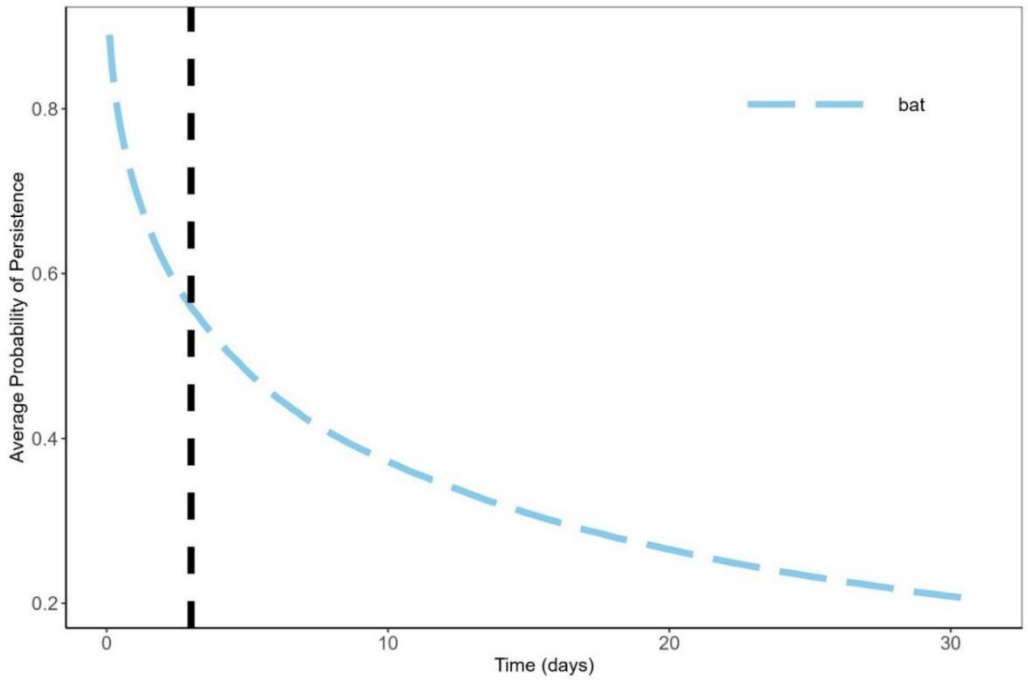

Figure 6. The average probability of persistence, in days, for bat carcasses on 70-meter cleared and uncleared plots at Hog Creek Wind Farm, Hardin County, Ohio, from August 1 – October 15, 2022.

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

Area Adjustment

One of the 117 bats found during the monitoring season was excluded from modeling the area adjustment for EoA because it was found off plot (Appendix C1). The TWL area adjustment for bats at 100-m road and pads was 0.20 (90% CI: 0.16-0.24) in the spring and 0.19 (90%CI fall.1: 0.16-0.24; 90% CI fall.2: 0.15-0.23; 90% CI fall.3: 0.15-0.23 in the fall. The TWL area adjustment for bats at 70-m plots was estimated to be 0.98 to 0.99 (90%CI fall.1: 0.96-0.99; 90% CI fall.2: 0.979-0.99; 90% CI fall.3: 0.97-0.99) in the fall (Figure 7, Appendix C2, Appendix C3).

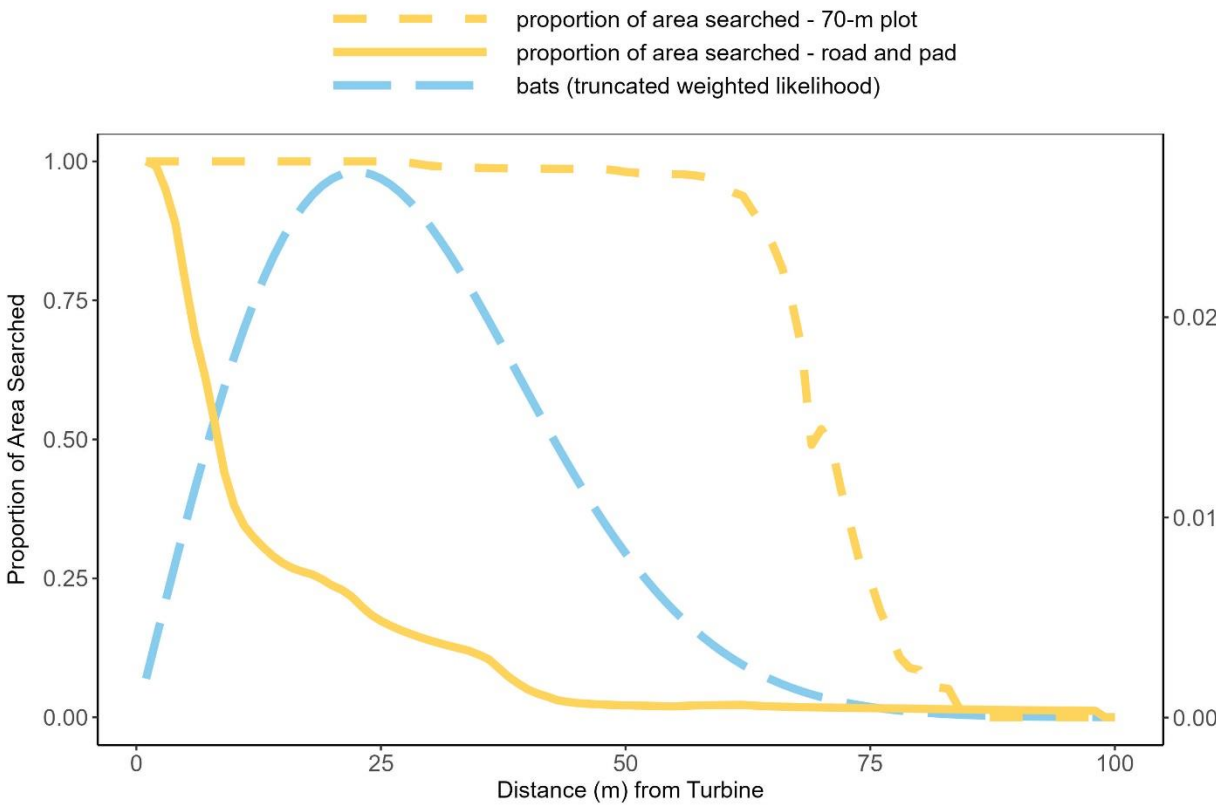

Figure 7. Density of bat carcasses per area searched at all 100-meter road and pads and 70-meter cleared and uncleared plots at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1– October 15, 2022.

Covered Species Take Estimates

No Covered Species carcasses were found during the study, and no Indiana bats or northern long-eared bats have been found to date under the ITP. The annual probability of detection distribution (*g*) achieved for the 2022 monitoring period had a mean of 0.20 (90% CI: 0.17–0.22; Table 6). 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 6. Annual probabilities of detection (*g*), Ba, Bb, and ρ for the Hog Creek Wind Farm, Hardin County, Ohio, from 2020–2022.

Year	Ba[1]	Bb[1]	ρ[2]	*g*	90% CI
2020	65.52	274.61	0.70	0.193	0.159-0.229
2021	218.39	575.95	1.00	0.268	0.244-0.293
2022	113.179	536.582	1.00	0.199	0.174-0.225
Short-term Trigger (Last 3 Years)	415.232	1447.388	NA	0.223	0.207-0.239
Long-term Trigger (Cumulative)	415.232	1447.388	NA	0.223	0.204-0.242

[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**.**

CI = confidence interval.

Mean annual take rates based on monitoring from three periods (2020–2022) were estimated to be 0.83 (95% CI: zero to 4.19) Indiana bats per year and 0.83 (95% CI: zero to 4.19) northern long-eared bats 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 bats per year.

Cumulative take under the ITP to-date (2020–2022), *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(λ > τ). At a 90% confidence level (α = 0.1), Pr(λ > τ) must be greater than or equal to 0.90 for the short-term trigger to fire. For Indiana bat, Pr(λ > τ) = 0.05, and northern long-eared bat, Pr(λ > τ) = 0.27 (Table 7). Neither probability meets or exceeds 0.90, indicating the short-term trigger was not met and no adaptive management actions are necessary (Table 8, Figure 8).

Table 7. 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 (2020–2022).

Species	Mean λ (90% Confidence Interval)	Expected Take Rate (τ)	Pr(λ > τ) *	Short-Term Trigger Fires at α = 0.1?
Indiana bat	0.83 (0.001–4.188)	3.3	0.05	No
Northern long-eared bat	0.83 (0.001–4.188)	1.0	0.27	No

* 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.

Table 8. 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 (2020–2022).

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

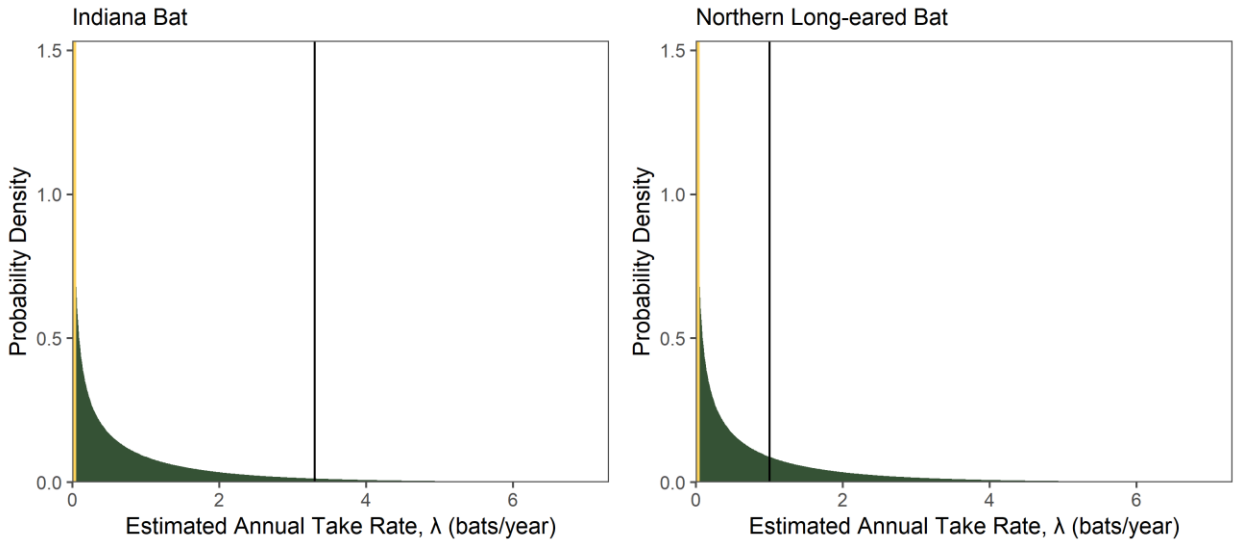

Figure 8. Estimated annual take rates (λ), in bats per year, at the Hog Creek Wind Farm, Hardin County, Ohio, Incidental Take Permit Years 1–3 (2020–2022).

Note: The yellow region of the posterior distributions shows the lower 5% 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 8). 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.

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 actions are necessary at this time.

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Appendix A Carcasses Found during the 2022 Post-construction Monitoring Surveys

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition	Aided Search
04/22/2022	silver-haired bat	37	24	carcass search	weekly road and pad	intact	no
05/13/2022	eastern red bat	31	28	carcass search	weekly road and pad	intact	no
05/13/2022	silver-haired bat	19	17	carcass search	weekly road and pad	intact	no
08/06/2022	big brown bat	20	17	carcass search	twice per week uncleared plot	intact	yes[1]
08/06/2022	big brown bat	50	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/06/2022	eastern red bat	10	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/08/2022	big brown bat	7	25	carcass search	twice per week cleared plot	intact	yes[1]
08/08/2022	big brown bat	5	30	carcass search	twice per week cleared plot	dismembered	yes[1]
08/08/2022	eastern red bat	36	2	carcass search	twice per week cleared plot	scavenged	yes[1]
08/08/2022	hoary bat	30	27	carcass search	twice per week cleared plot	intact	yes[1]
08/11/2022	big brown bat	18	30	carcass search	twice per week cleared plot	dismembered	yes[1]
08/11/2022	eastern red bat	17	15	carcass search	weekly road and pad	intact	no
08/11/2022	eastern red bat	19	2	carcass search	twice per week cleared plot	intact	yes[1]
08/11/2022	hoary bat	36	27	carcass search	twice per week cleared plot	scavenged	yes[1]
08/15/2022	eastern red bat	26	27	carcass search	twice per week cleared plot	scavenged	yes[1]
08/18/2022	big brown bat	11	2	carcass search	twice per week cleared plot	scavenged	yes[1]
08/18/2022	big brown bat	40	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/18/2022	big brown bat	42	30	carcass search	twice per week cleared plot	scavenged	yes[1]
08/23/2022	big brown bat	27	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/24/2022	big brown bat	4	1	carcass search	twice per week cleared plot	scavenged	yes[1]
08/24/2022	eastern red bat	45	5	carcass search	twice per week cleared plot	scavenged	yes[1]
08/26/2022	eastern red bat	42	27	carcass search	twice per week cleared plot	scavenged	yes[1]
08/26/2022	eastern red bat	66	27	carcass search	twice per week cleared plot	scavenged	yes[1]
08/26/2022	eastern red bat	21	7	carcass search	twice per week cleared plot	scavenged	no
08/27/2022	big brown bat	2	1	carcass search	twice per week cleared plot	scavenged	yes[1]
08/27/2022	big brown bat	9	24	carcass search	weekly road and pad	intact	no
08/27/2022	eastern red bat	8	28	carcass search	weekly road and pad	intact	no
08/29/2022	big brown bat	12	27	carcass search	twice per week cleared plot	scavenged	yes[1]
08/29/2022	big brown bat	33	30	carcass search	twice per week cleared plot	feather spot	yes[1]
08/29/2022	big brown bat	28	30	carcass search	twice per week cleared plot	scavenged	yes[1]
08/29/2022	big brown bat	29	30	carcass search	twice per week cleared plot	scavenged	yes[1]
08/29/2022	eastern red bat	66	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/29/2022	eastern red bat	39	30	carcass search	twice per week cleared plot	scavenged	yes[1]
08/29/2022	hoary bat	42	2	carcass search	twice per week cleared plot	scavenged	yes[1]

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition	Aided Search
08/29/2022	hoary bat	18	7	carcass search	twice per week cleared plot	intact	no
08/29/2022	silver-haired bat	43	25	carcass search	twice per week cleared plot	scavenged	yes[1]
08/30/2022	eastern red bat	17	23	carcass search	weekly road and pad	intact	no
08/30/2022	eastern red bat	49	6	carcass search	twice per week cleared plot	intact	no
08/30/2022	hoary bat	0	5	carcass search	twice per week cleared plot	intact	yes[1]
09/01/2022	big brown bat	7	1	incidental	twice per week cleared plot	scavenged	yes[1]
09/01/2022	big brown bat	48	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/01/2022	hoary bat	5	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/01/2022	hoary bat	45	3	carcass search	twice per week cleared plot	intact	yes[1]
09/01/2022	silver-haired bat	25	15	carcass search	weekly road and pad	intact	no
09/01/2022	silver-haired bat	35	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/01/2022	silver-haired bat	28	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/02/2022	big brown bat	21	17	carcass search	twice per week uncleared plot	intact	yes[1]
09/02/2022	big brown bat	25	5	carcass search	twice per week cleared plot	intact	yes[1]
09/02/2022	eastern red bat	42	5	carcass search	twice per week cleared plot	intact	yes[1]
09/02/2022	eastern red bat	39	5	carcass search	twice per week cleared plot	scavenged	yes[1]
09/02/2022	silver-haired bat	44	5	carcass search	twice per week cleared plot	intact	yes[1]
09/02/2022	silver-haired bat	27	5	carcass search	twice per week cleared plot	intact	yes[1]
09/02/2022	silver-haired bat	7	5	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	eastern red bat	14	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	eastern red bat	17	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	eastern red bat	37	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	eastern red bat	52	27	carcass search	twice per week cleared plot	intact	yes[1]
09/05/2022	eastern red bat	26	27	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	eastern red bat	40	30	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	hoary bat	43	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	silver-haired bat	5	10	carcass search	twice per week cleared plot	scavenged	no
09/05/2022	silver-haired bat	28	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	silver-haired bat	7	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	silver-haired bat	40	27	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	silver-haired bat	18	27	carcass search	twice per week cleared plot	scavenged	yes[1]
09/05/2022	silver-haired bat	33	30	carcass search	twice per week cleared plot	scavenged	yes[1]
09/06/2022	silver-haired bat	37	1	carcass search	twice per week cleared plot	intact	yes[1]
09/06/2022	silver-haired bat	45	5	carcass search	twice per week cleared plot	scavenged	yes[1]
09/06/2022	silver-haired bat	48	5	carcass search	twice per week cleared plot	scavenged	yes[1]

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition	Aided Search
09/08/2022	eastern red bat	32	30	incidental	twice per week cleared plot	scavenged	yes[1]
09/09/2022	big brown bat	51	17	carcass search	twice per week uncleared plot	scavenged	yes[1]
09/09/2022	hoary bat	32	5	carcass search	twice per week cleared plot	intact	yes[1]
09/09/2022	silver-haired bat	45	1	carcass search	twice per week cleared plot	scavenged	yes[1]
09/09/2022	silver-haired bat	37	5	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	eastern red bat	11	11	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	eastern red bat	31	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	eastern red bat	51	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	eastern red bat	54	30	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	silver-haired bat	65	11	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	silver-haired bat	12	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/12/2022	silver-haired bat	48	27	carcass search	twice per week cleared plot	scavenged	yes[1]
09/13/2022	eastern red bat	12	23	carcass search	weekly road and pad	intact	no
09/15/2022	big brown bat	14	16	carcass search	weekly road and pad	intact	no
09/15/2022	eastern red bat	54	25	carcass search	twice per week cleared plot	intact	yes[1]
09/15/2022	silver-haired bat	43	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/16/2022	hoary bat	33	28	carcass search	weekly road and pad	intact	no
09/19/2022	eastern red bat	21	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/19/2022	eastern red bat	24	7	carcass search	twice per week cleared plot	scavenged	yes[1]
09/19/2022	silver-haired bat	31	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/20/2022	eastern red bat	21	1	carcass search	twice per week cleared plot	intact	yes[1]
09/20/2022	eastern red bat	50	1	carcass search	twice per week cleared plot	intact	yes[1]
09/20/2022	hoary bat	8	1	carcass search	twice per week cleared plot	scavenged	yes[1]
09/20/2022	silver-haired bat	36	17	carcass search	twice per week uncleared plot	intact	yes[1]
09/22/2022	eastern red bat	59	3	carcass search	twice per week cleared plot	intact	yes[1]
09/23/2022	eastern red bat	42	6	carcass search	twice per week cleared plot	intact	yes[1]
09/23/2022	hoary bat	36	6	carcass search	twice per week cleared plot	intact	yes[1]
09/26/2022	eastern red bat	40	2	carcass search	twice per week cleared plot	scavenged	yes[1]
09/26/2022	eastern red bat	74	27	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
09/26/2022	eastern red bat	21	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/26/2022	silver-haired bat	20	3	carcass search	twice per week cleared plot	intact	yes[1]
09/26/2022	silver-haired bat	24	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/26/2022	silver-haired bat	65	30	carcass search	twice per week cleared plot	scavenged	yes[1]
09/27/2022	silver-haired bat	29	17	carcass search	twice per week uncleared plot	intact	yes[1]
09/30/2022	eastern red bat	24	29	carcass search	weekly road and pad	intact	no

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition	Aided Search
09/30/2022	silver-haired bat	60	1	carcass search	twice per week cleared plot	intact	yes[1]
09/30/2022	silver-haired bat	29	28	carcass search	weekly road and pad	intact	no
10/03/2022	eastern red bat	49	11	carcass search	twice per week cleared plot	intact	yes[1]
10/03/2022	eastern red bat	40	25	carcass search	twice per week cleared plot	intact	yes[1]
10/03/2022	silver-haired bat	60	25	carcass search	twice per week cleared plot	intact	yes[1]
10/03/2022	silver-haired bat	23	30	carcass search	twice per week cleared plot	scavenged	yes[1]
10/03/2022	silver-haired bat	20	4	carcass search	weekly road and pad	intact	no
10/06/2022	big brown bat	45	27	carcass search	twice per week cleared plot	scavenged	yes[1]
10/06/2022	eastern red bat	62	30	carcass search	twice per week cleared plot	scavenged	yes[1]
10/06/2022	silver-haired bat	20	11	carcass search	twice per week cleared plot	scavenged	yes[1]
10/10/2022	eastern red bat	57	30	carcass search	twice per week cleared plot	scavenged	yes[1]
10/10/2022	silver-haired bat	56	30	carcass search	twice per week cleared plot	scavenged	yes[1]
10/13/2022	eastern red bat	66	2	carcass search	twice per week cleared plot	intact	yes[1]
04/29/2022	yellow-throated vireo	36	30	carcass search	weekly road and pad	intact	no
05/06/2022	common yellowthroat	18	21	carcass search	weekly road and pad	intact	no
05/13/2022	American redstart	19	21	carcass search	weekly road and pad	intact	no
05/13/2022	northern rough-winged swallow	19	9	carcass search	weekly road and pad	intact	no
08/06/2022	tree swallow	39	17	carcass search	twice per week uncleared plot	feather spot	yes[1]
08/06/2022	turkey vulture	54	17	carcass search	twice per week uncleared plot	scavenged	yes[1]
08/09/2022	horned lark	45	5	carcass search	twice per week cleared plot	scavenged	yes[1]
08/11/2022	American crow	24	16	carcass search	weekly road and pad	feather spot	no
08/11/2022	horned lark	7	14	carcass search	weekly road and pad	scavenged	no
08/12/2022	tree swallow	29	1	carcass search	twice per week cleared plot	feather spot	yes[1]
08/12/2022	tree swallow	36	1	carcass search	twice per week cleared plot	feather spot	yes[1]
08/12/2022	unidentified kinglet	3	1	carcass search	twice per week cleared plot	scavenged	yes[1]
08/15/2022	chimney swift	37	2	carcass search	twice per week cleared plot	scavenged	yes[1]
08/15/2022	tree swallow	29	2	carcass search	twice per week cleared plot	scavenged	yes[1]
08/16/2022	turkey vulture	42	17	carcass search	twice per week uncleared plot	scavenged	yes[1]
08/18/2022	Canada goose	48	3	carcass search	twice per week cleared plot	scavenged	yes[1]
08/18/2022	horned lark	20	27	carcass search	twice per week cleared plot	feather spot	yes[1]
08/19/2022	killdeer	25	5	carcass search	twice per week cleared plot	feather spot	yes[1]
08/23/2022	horned lark	25	30	carcass search	twice per week cleared plot	scavenged	yes[1]
08/26/2022	horned lark	17	2	carcass search	twice per week cleared plot	feather spot	yes[1]
08/26/2022	tree swallow	25	7	carcass search	twice per week cleared plot	feather spot	no

Appendix A. Bird and bat carcasses found at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Found Date	Species	Distance from Turbine (m)	Turbine	Search Type	Search Area Type	Physical Condition	Aided Search
08/27/2022	horned lark	36	5	carcass search	twice per week cleared plot	feather spot	yes[1]
08/27/2022	horned lark	43	5	carcass search	twice per week cleared plot	feather spot	yes[1]
08/30/2022	killdeer	63	5	carcass search	twice per week cleared plot	feather spot	yes[1]
09/01/2022	horned lark	57	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/02/2022	horned lark	42	5	carcass search	twice per week cleared plot	intact	yes[1]
09/05/2022	horned lark	66	2	carcass search	twice per week cleared plot	intact	yes[1]
09/05/2022	killdeer	63	27	carcass search	twice per week cleared plot	feather spot	yes[1]
09/05/2022	purple martin	71	11	carcass search	twice per week cleared plot	scavenged	yes[1]
09/08/2022	horned lark	35	25	carcass search	twice per week cleared plot	dismembered	yes[1]
09/08/2022	horned lark	57	3	carcass search	twice per week cleared plot	scavenged	yes[1]
09/08/2022	mourning dove	68	3	carcass search	twice per week cleared plot	feather spot	yes[1]
09/09/2022	tree swallow	36	25	incidental	twice per week cleared plot	scavenged	yes[1]
09/12/2022	brown-headed cowbird	73	7	carcass search[2]	twice per week cleared plot	scavenged	yes[1]
09/12/2022	brown-headed cowbird	67	7	carcass search	twice per week cleared plot	feather spot	yes[1]
09/12/2022	European starling	57	25	carcass search	twice per week cleared plot	scavenged	yes[1]
09/16/2022	killdeer	24	10	carcass search	twice per week cleared plot	intact	yes[1]
09/19/2022	killdeer	56	10	carcass search	twice per week cleared plot	dismembered	yes[1]
09/20/2022	killdeer	28	1	carcass search	twice per week cleared plot	feather spot	yes[1]
09/22/2022	horned lark	26	11	carcass search	twice per week cleared plot	scavenged	yes[1]
09/27/2022	unidentified dove	14	6	carcass search	twice per week cleared plot	feather spot	yes[1]
09/29/2022	mourning dove	46	3	carcass search	twice per week cleared plot	feather spot	yes[1]
09/30/2022	horned lark	6	6	carcass search	twice per week cleared plot	intact	yes[1]
10/04/2022	house sparrow	50	19	carcass search	weekly road and pad	scavenged	no
10/06/2022	golden-crowned kinglet	42	2	carcass search	twice per week cleared plot	scavenged	yes[1]
10/06/2022	mourning dove	9	30	carcass search	twice per week cleared plot	feather spot	yes[1]
10/10/2022	golden-crowned kinglet	58	11	carcass search	twice per week cleared plot	scavenged	yes[1]

[1] Dog aided search.

[2] Carcass was found outside the search area.

m = meters.

Appendix B. Searcher Efficiency and Carcass Persistence Model Fitting Results

Appendix B1. Searcher efficiency models for 100-meter road and pads at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022 (n = 53 carcasses).

Covariates	k Value	AICc	Delta AICc
No Covariates	0.67	25.14	0*
Season	0.67	26.98	1.84

* Selected model.

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

Appendix B2. Searcher efficiency models for 70-meter cleared and uncleared plots at the Hog Creek Wind Farm, Hardin County, Ohio, from August 1 – October 15, 2022 (n = 34 carcasses).

Covariates	k Value	AICc	Delta AICc
No Covariates	0.67	36.70	0*
Plot Search Type	0.67	37.30	0.60

* Selected model.

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

Appendix B3. Carcass persistence models with covariates and distributions for bats on 100-meter road and pads at the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022 (n = 27 carcasses).

Location Covariates	Scale Covariates	Distribution	AICc	Delta AICc
Season	No Covariates	Weibull	115.43	0*
Season	Season	Weibull	117.39	1.96
Season	-	exponential	118.25	2.82
No Covariates	No Covariates	Weibull	118.28	2.85
No Covariates	Season	Weibull	119.15	3.72
Season	No Covariates	loglogistic	119.95	4.52
No Covariates	No Covariates	loglogistic	120.51	5.08
No Covariates	Season	lognormal	120.64	5.21
Season	No Covariates	lognormal	120.86	5.43
No Covariates	No Covariates	lognormal	120.96	5.53
No Covariates	Season	loglogistic	121.16	5.73
Season	Season	loglogistic	121.45	6.02
Season	Season	lognormal	121.55	6.12
No Covariates	-	exponential	128.27	12.84

* Selected model.

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

Appendix B4. Carcass persistence models with covariates and distributions for bats on 70-meter cleared and uncleared plots at the Hog Creek Wind Farm, Hardin County, Ohio, from August 1 – October 15, 2022 (n = 17 carcasses).

Location Covariates	Scale Covariates	Distribution	AICc	Delta AICc
No Covariates	No Covariates	Weibull	68.22	0*
No Covariates	No Covariates	lognormal	68.77	0.55
No Covariates	No Covariates	loglogistic	69.23	1.01
No Covariates	PlotSearchType	Weibull	69.40	1.18
No Covariates	PlotSearchType	lognormal	70.12	1.90
PlotSearchType	No Covariates	Weibull	70.60	2.38
No Covariates	PlotSearchType	loglogistic	70.96	2.74
PlotSearchType	No Covariates	lognormal	71.68	3.46
PlotSearchType	No Covariates	loglogistic	72.21	3.99
PlotSearchType	PlotSearchType	Weibull	72.78	4.56
PlotSearchType	PlotSearchType	lognormal	73.61	5.39
PlotSearchType	PlotSearchType	loglogistic	74.44	6.22
No Covariates	-	exponential	77.11	8.89
PlotSearchType	-	exponential	77.77	9.55

* Selected model.

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

Appendix C. Truncated Weighted Likelihood Area Adjustment Model Fitting Results

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 and August 1 – October 15, 2022.

	Included in Area Adjustment		Outside Search Area*		Outside Study Period*		Total	
Species	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
eastern red bat	44	37.9	1	100	0	-	45	38.5
silver-haired bat	37	31.9	0	-	0	-	37	31.6
big brown bat	23	19.8	0	-	0	-	23	19.7
hoary bat	12	10.3	0	-	0	-	12	10.3
Total	**116**	**100**	**1**	**100**	**0**	-	**117**	**100**

* Carcasses not included in analysis.

Sums may not equal totals shown due to rounding.

Appendix C2. Search area adjustment models for bats from the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Distribution	AICc	Delta AICc
Weibull	4,576.46	0*
normal	4,580.18	3.72
Gompertz	4,604.20	27.74
gamma	4,608.03	31.57

* Selected model.

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

Appendix C3. Truncated weighted maximum likelihood search area estimates for the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Search Area Type	Distribution	Parameter 1	Parameter 2	Area Adjustment	Season
twice per week plot	Weibull	2.0154	31.7115	0.98	Fall 1
twice per week plot	Weibull	2.0154	31.7115	0.98	Fall 2
twice per week plot	Weibull	2.0154	31.7115	0.99	Fall 3
weekly road and pad	Weibull	2.0154	31.7115	0.19	Fall 1
weekly road and pad	Weibull	2.0154	31.7115	0.19	Fall 2
weekly road and pad	Weibull	2.0154	31.7115	0.19	Fall 3
weekly road and pad	Weibull	2.0154	31.7115	0.20	Spring

n = 116 bats.

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 Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.*

Season	Plot Type	# of Turbines	Search Interval (I)	Number of Searches	Spatial Coverage (a)	Temporal Coverage	Searcher Efficiency		Carcass Persistence			
							Carcasses Available	Carcasses Found	Shape (α)	Scale (β)	β 95% CI Lower	β 95% CI Upper
Spring	100-m road and pad	30	7	7	0.1973	1	53	50	0.654	10.412	4.486	24.167
Fall 1	100-m road and pad	16	7	3	0.1888	1	53	50	0.654	2.166	0.875	5.366
Fall 2		17	7	3	0.1888	1	53	50	0.654	2.166	0.875	5.366
Fall 3		17	7	5	0.1888	1	53	50	0.654	2.166	0.875	5.366
Fall 1	70-m cleared plot	7	3.5	6	0.9818	1	34	27	0.484	4.007	1.358	11.822
Fall 2		10	3.5	5	0.9846	1	34	27	0.484	4.007	1.358	11.822
Fall 3		11	3.5	9	0.9856	1	34	27	0.484	4.007	1.358	11.822
Fall 1	70-m uncleared plot	2	3.5	6	0.9818	1	34	27	0.484	4.007	1.358	11.822
Fall 2		2	3.5	6	0.9846	1	34	27	0.484	4.007	1.358	11.822
Fall 3		2	3.5	8	0.9856	1	34	27	0.484	4.007	1.358	11.822

* *k* was assumed to equal 0.67 for all strata, per Huso et al. (2017). A Weibull distribution was assumed for carcass persistence.

CI = confidence interval; 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 Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

Season	Plot Type	Ba	Bb	Within-Season Sampling Fraction
Spring	100-m road and pad	55.10143	403.9678	1.00
Fall 1	100-m road and pad	10.89201	176.9116	0.53
Fall 2	100-m road and pad	10.86716	180.7402	0.57
Fall 3	100-m road and pad	11.02285	182.0849	0.57
Fall 1	70-m cleared plot	16.95774	20.29167	0.23
Fall 2	70-m cleared plot	17.12973	20.42555	0.33
Fall 3	70-m cleared plot	16.31384	19.14092	0.37
Fall 1	70-m uncleared plot	16.72357	19.92075	0.07
Fall 2	70-m uncleared plot	16.66232	19.76423	0.07
Fall 3	70-m uncleared plot	15.89483	18.50612	0.07
Fall 1	unsearched plot	0.01000	1,000.00000	0.17
Fall 2	unsearched plot	0.01000	1,000.00000	0.03

m = meter.

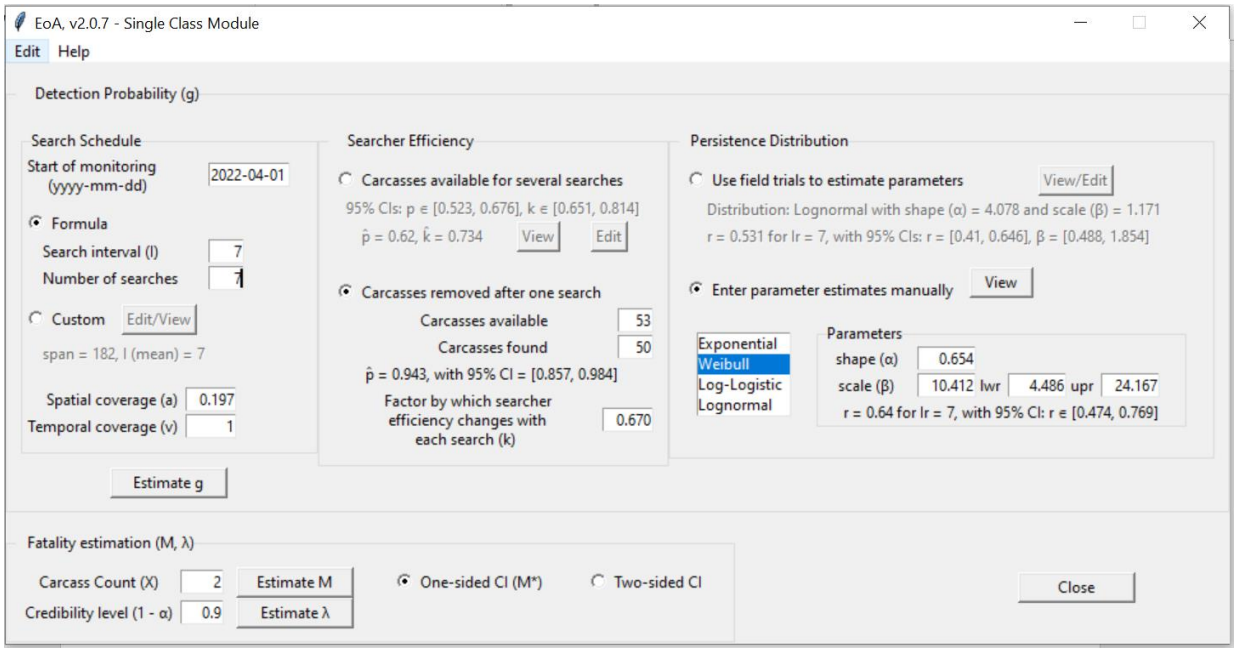
Appendix D3. Inputs needed to run Evidence of Absence model to combine across seasons: Multiple Class Module for the Hog Creek Wind Farm, Hardin County, Ohio, from April 1 – May 15 and August 1 – October 15, 2022.

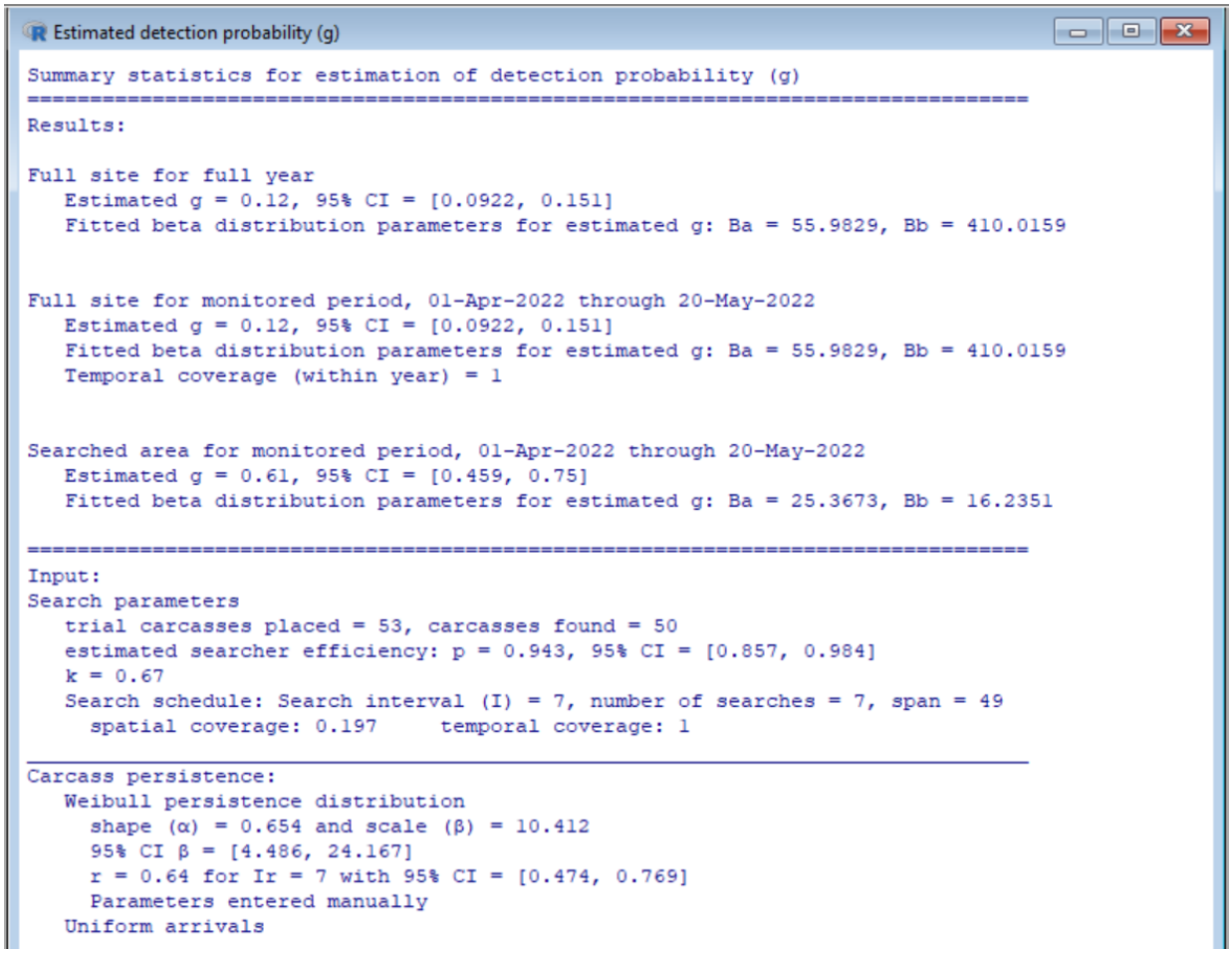
Season	Ba	Bb	Weights (DWP)
Spring (April 1–May 15)	55.1014	403.9678	0.11
Fall 1 (August 1 – August 25)	50.1501	249.1053	0.25
Fall 2 (August 26 – September 14)	43.2024	158.0441	0.25
Fall 3 (September 15 – October 15)	39.6143	131.2372	0.38

DWP = Density-weighted proportion.

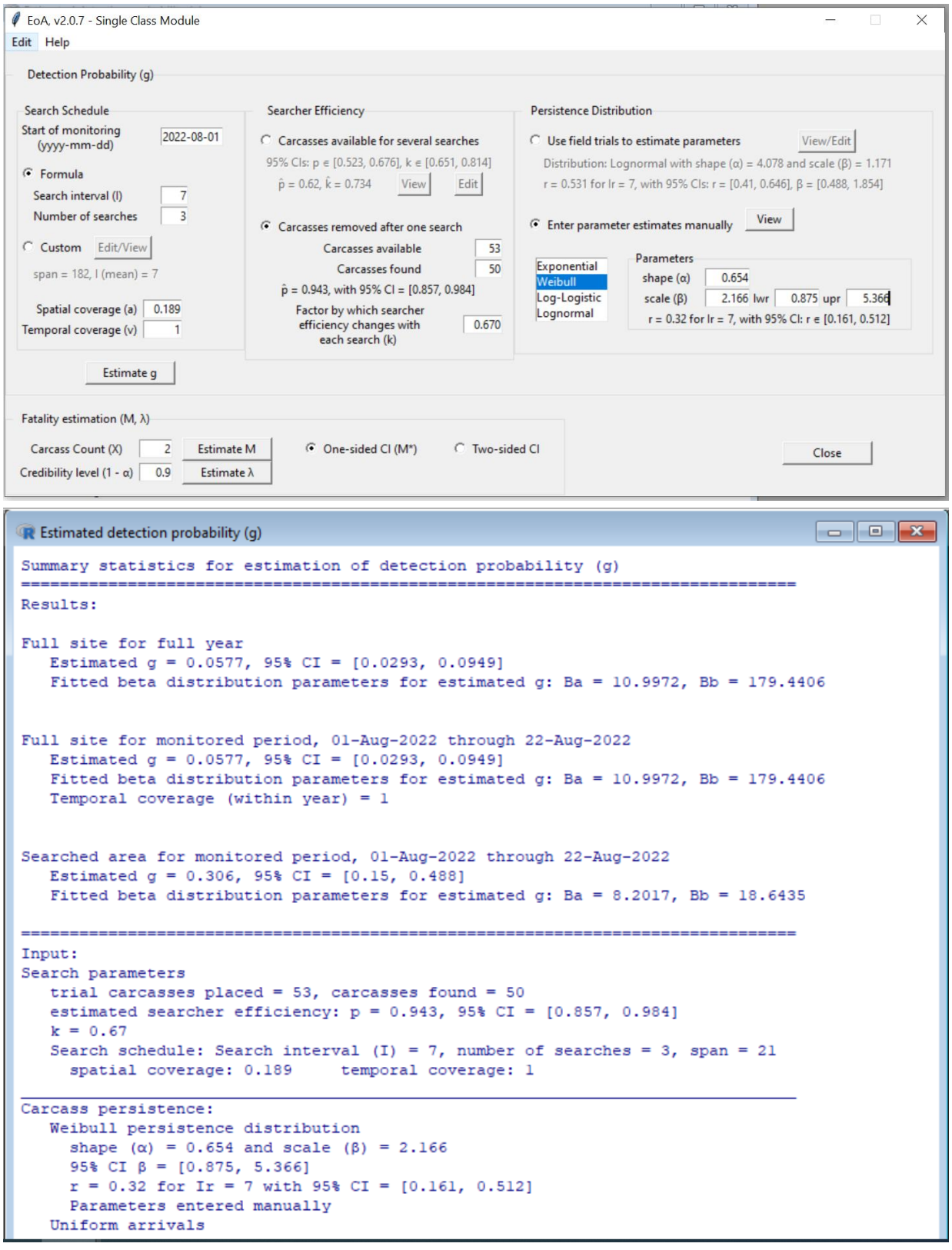
Appendix D4. Inputs needed to run Evidence of Absence model to combine across years: Multiple Years Module for the Hog Creek Wind Farm, Hardin County, Ohio, from 2020–2022.

Year	Ba	Bb	Weights (ρ)
2020	65.5200	274.6100	0.7
2021	242.6300	661.9600	1.0
2022	133.1786	536.5817	1.0

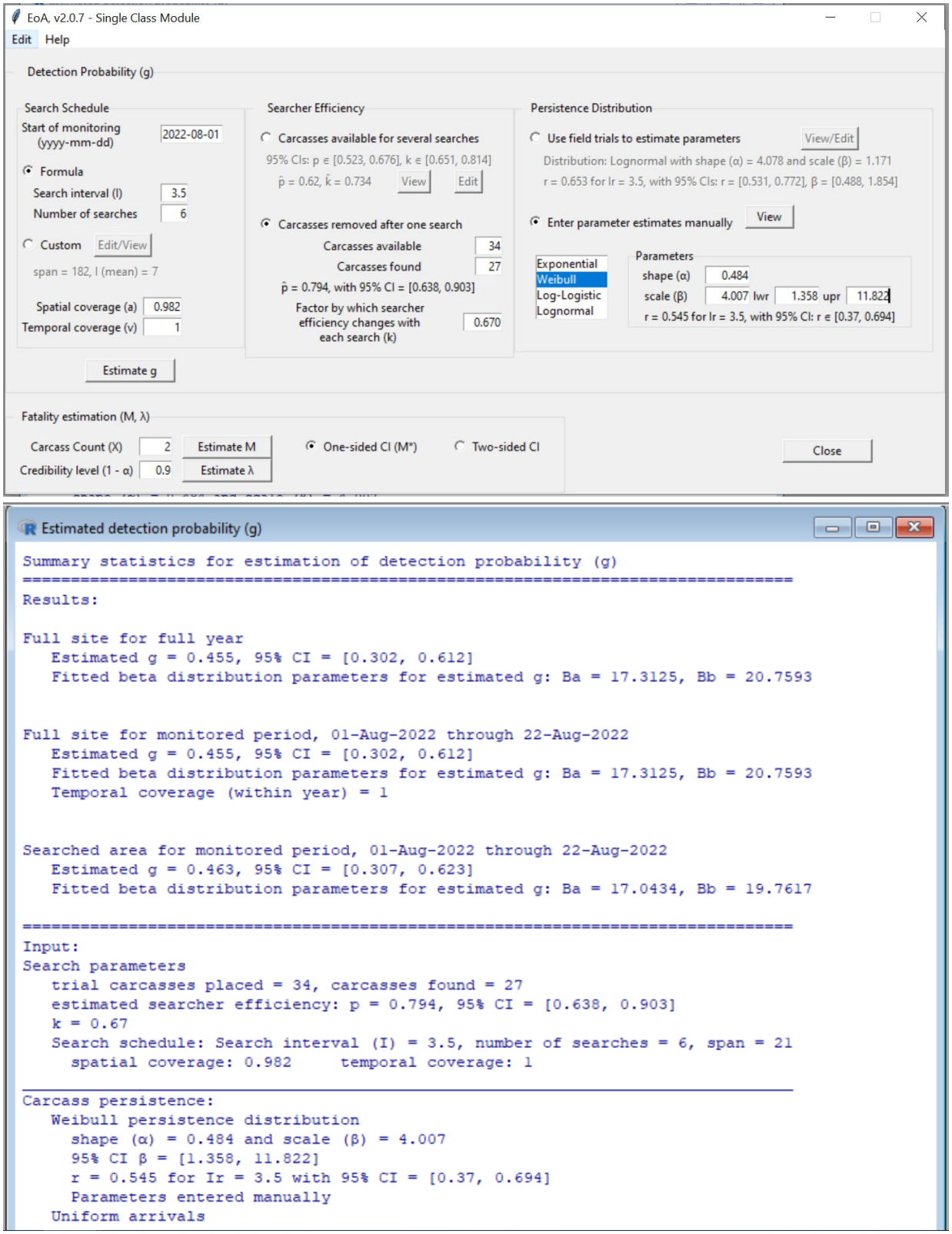




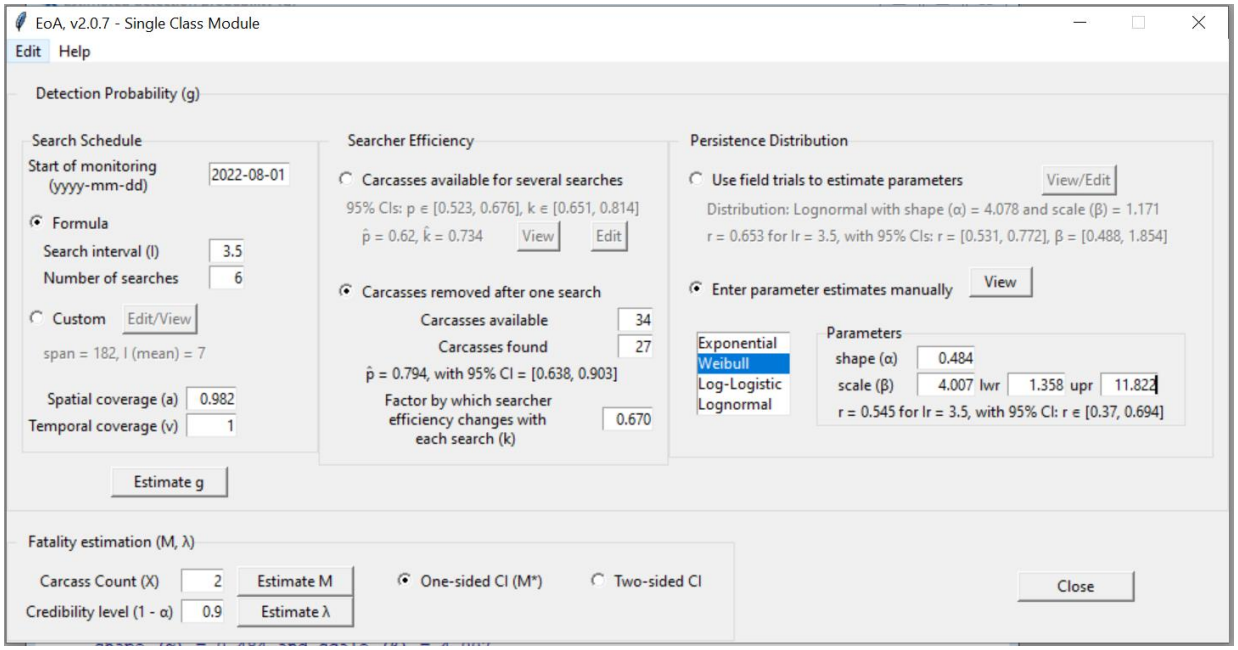
Appendix D5. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Spring 2022, 100-meter road and pad searches at 30 turbines, searched at a 7-day interval.

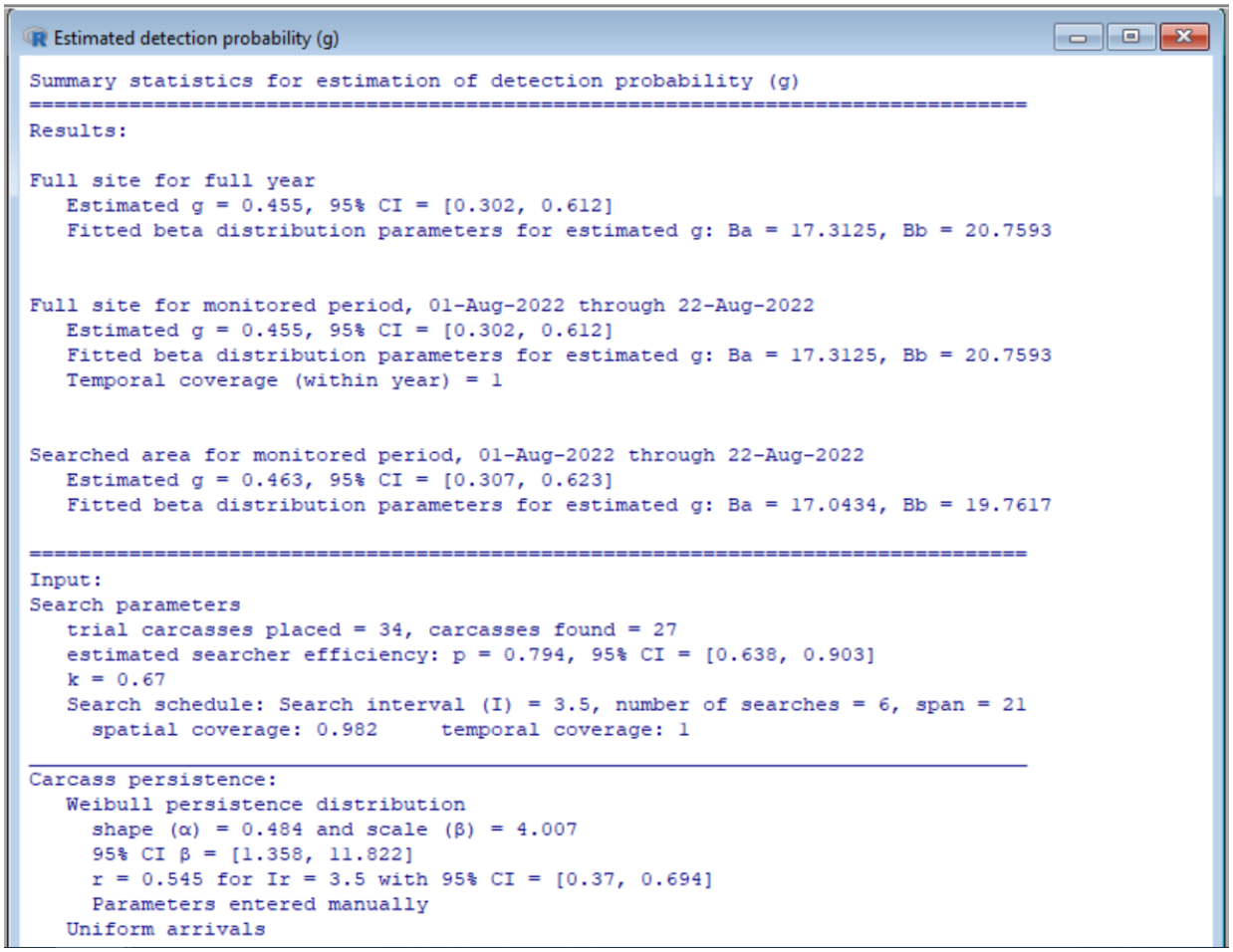


Appendix D6. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 1, 2022, 100-meter road and pad searches at 16 turbines, searched at a 7-day interval.

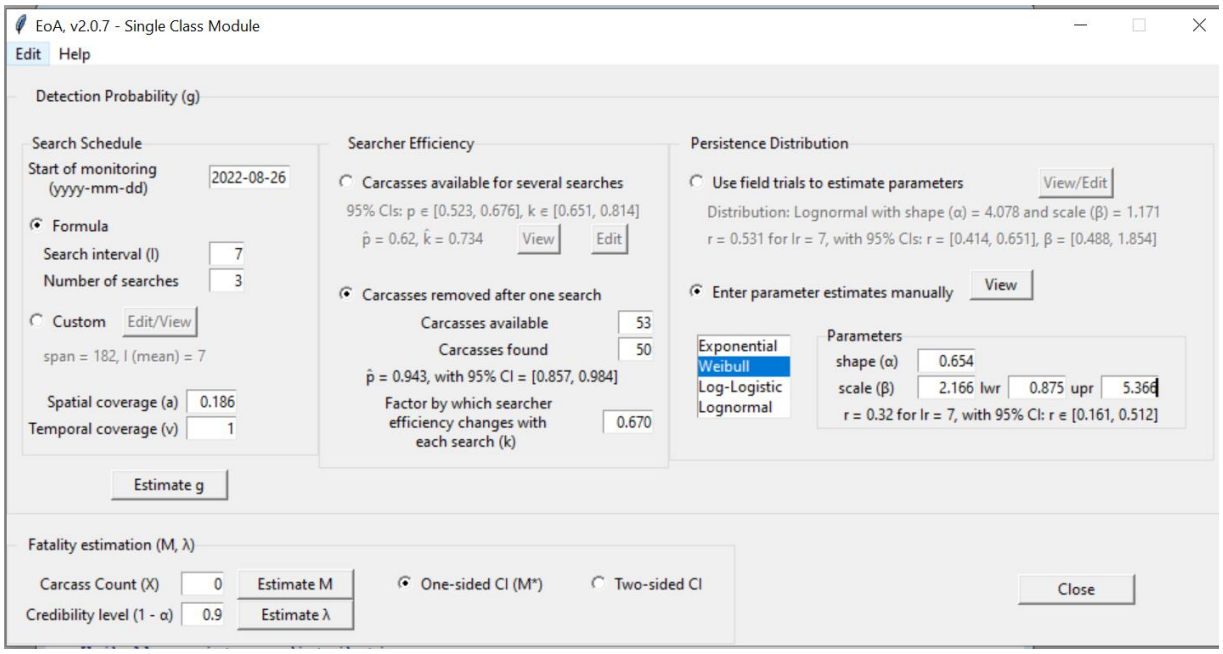


Appendix D7. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 1, 2022, 70-meter cleared plot searches at seven turbines, searched at a 3.5-day interval.

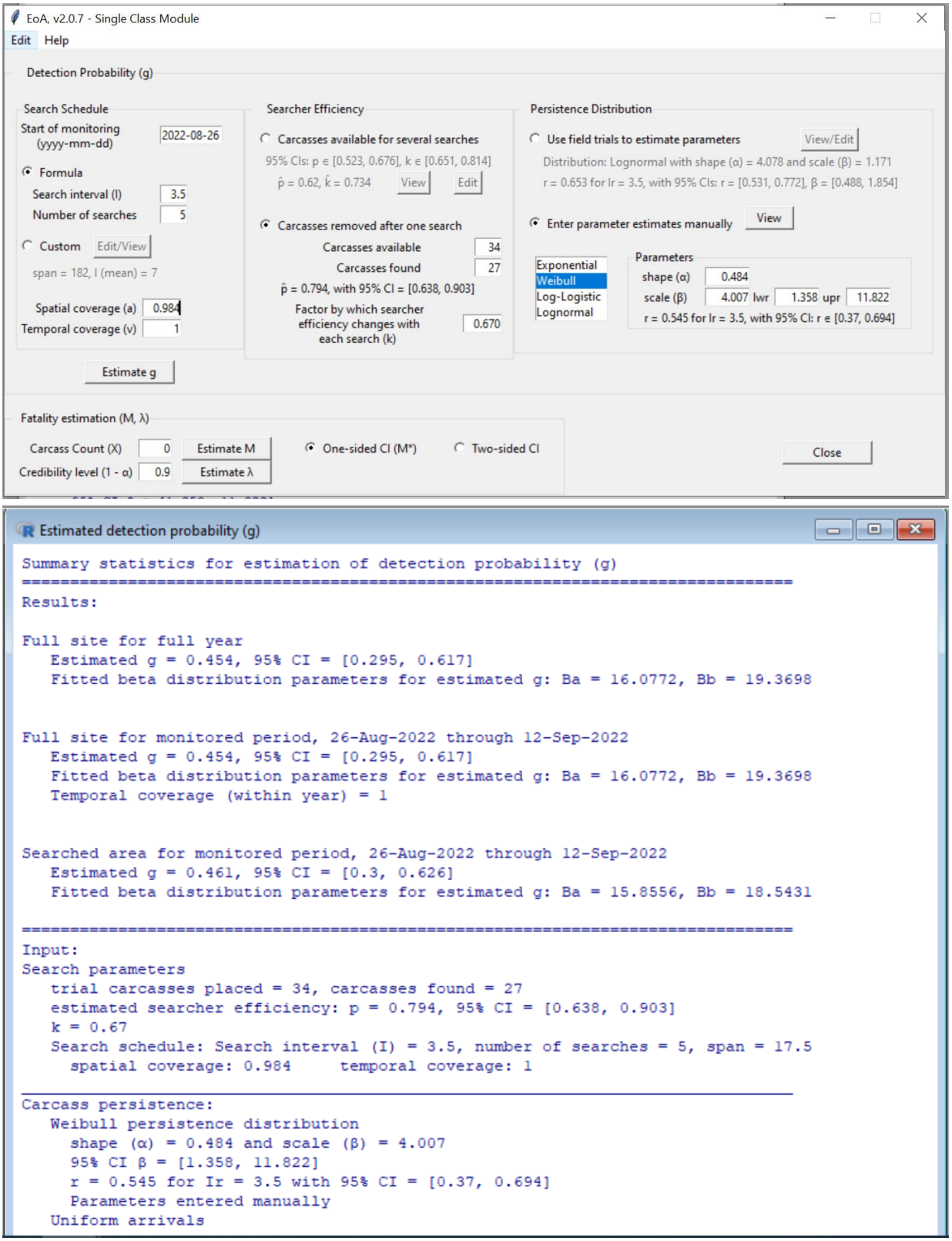




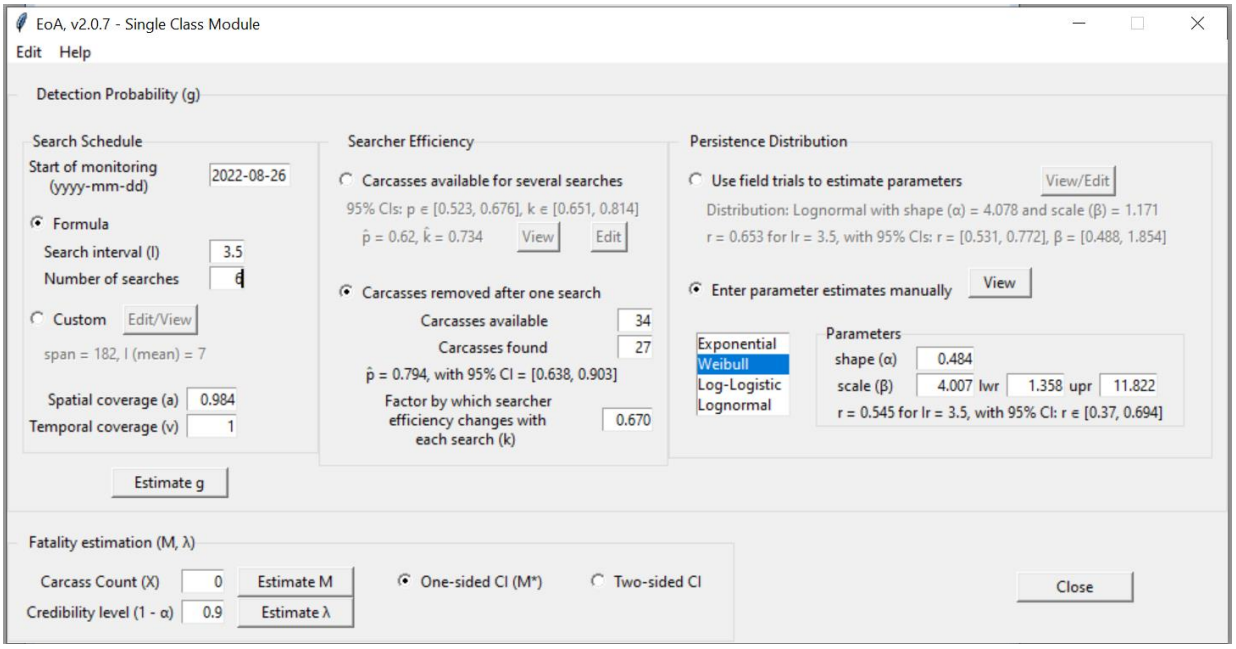
Appendix D8. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 1, 2022, 70-meter uncleared plot searches at two turbines, searched at a 3.5-day interval.

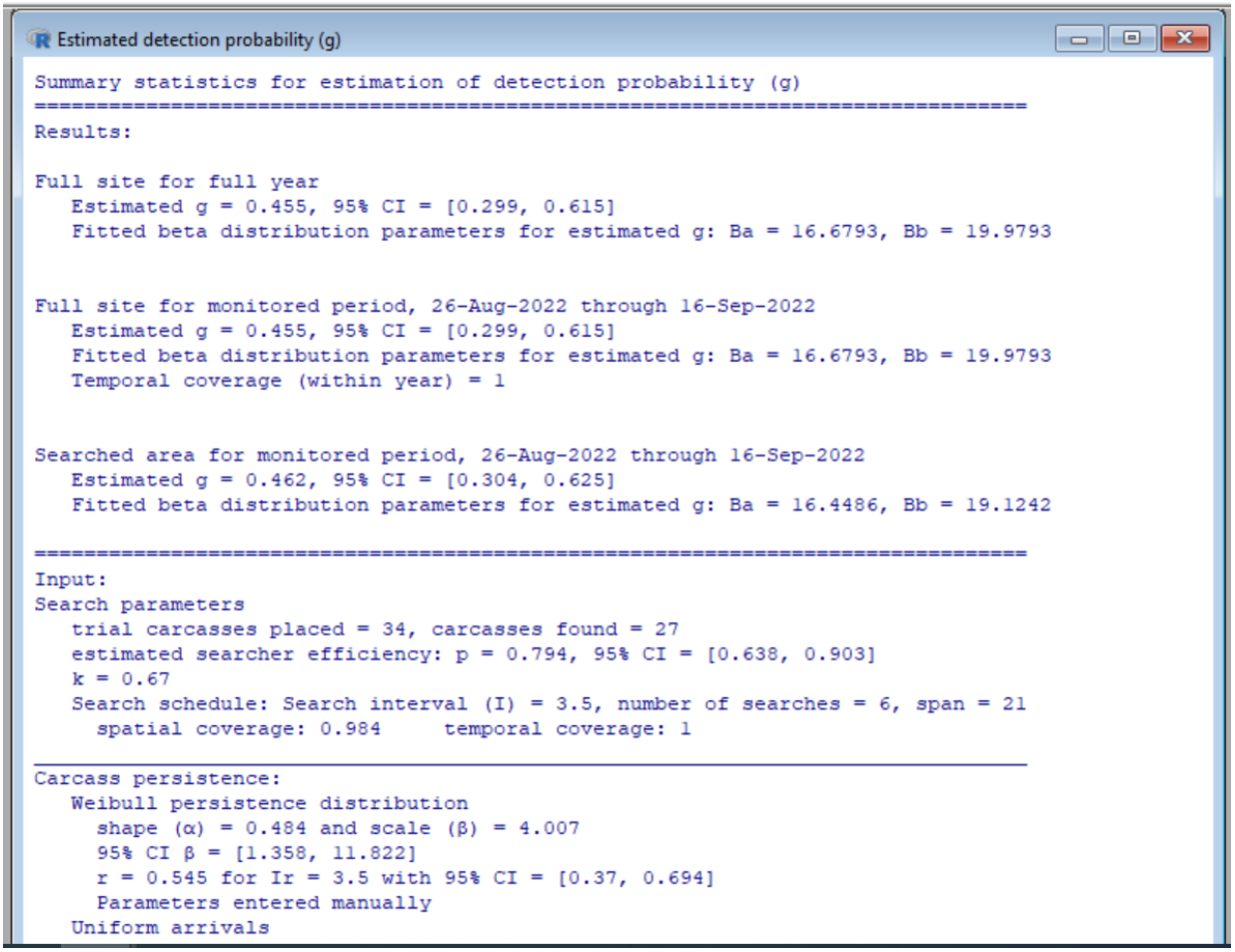


Appendix D9. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 2, 2022, 100-meter road and pad plot searches at 17 turbines, searched at a 7-day interval.

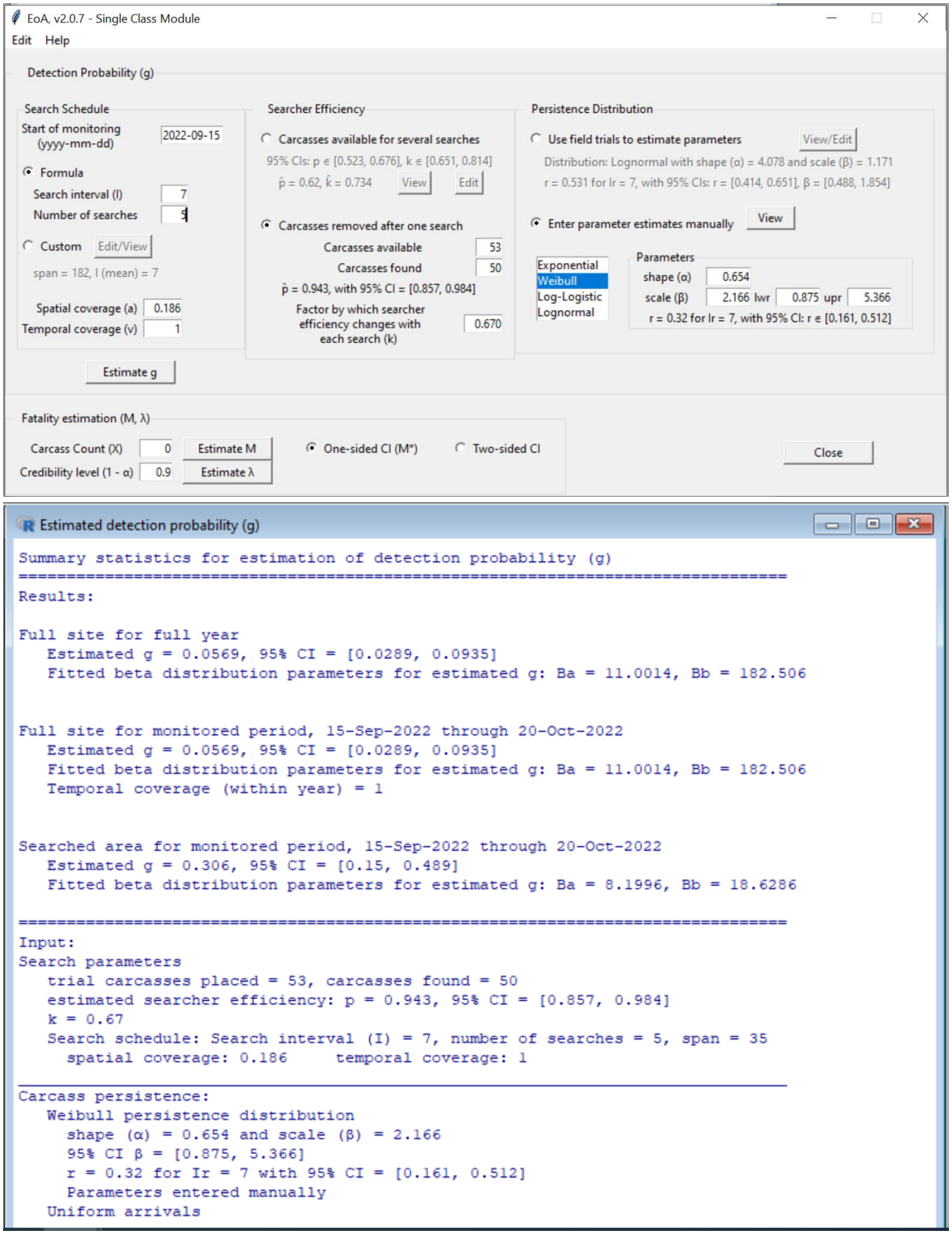


Appendix D10. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 2, 2022, 70-meter cleared plot searches at 10 turbines, searched at a 3.5-day interval.

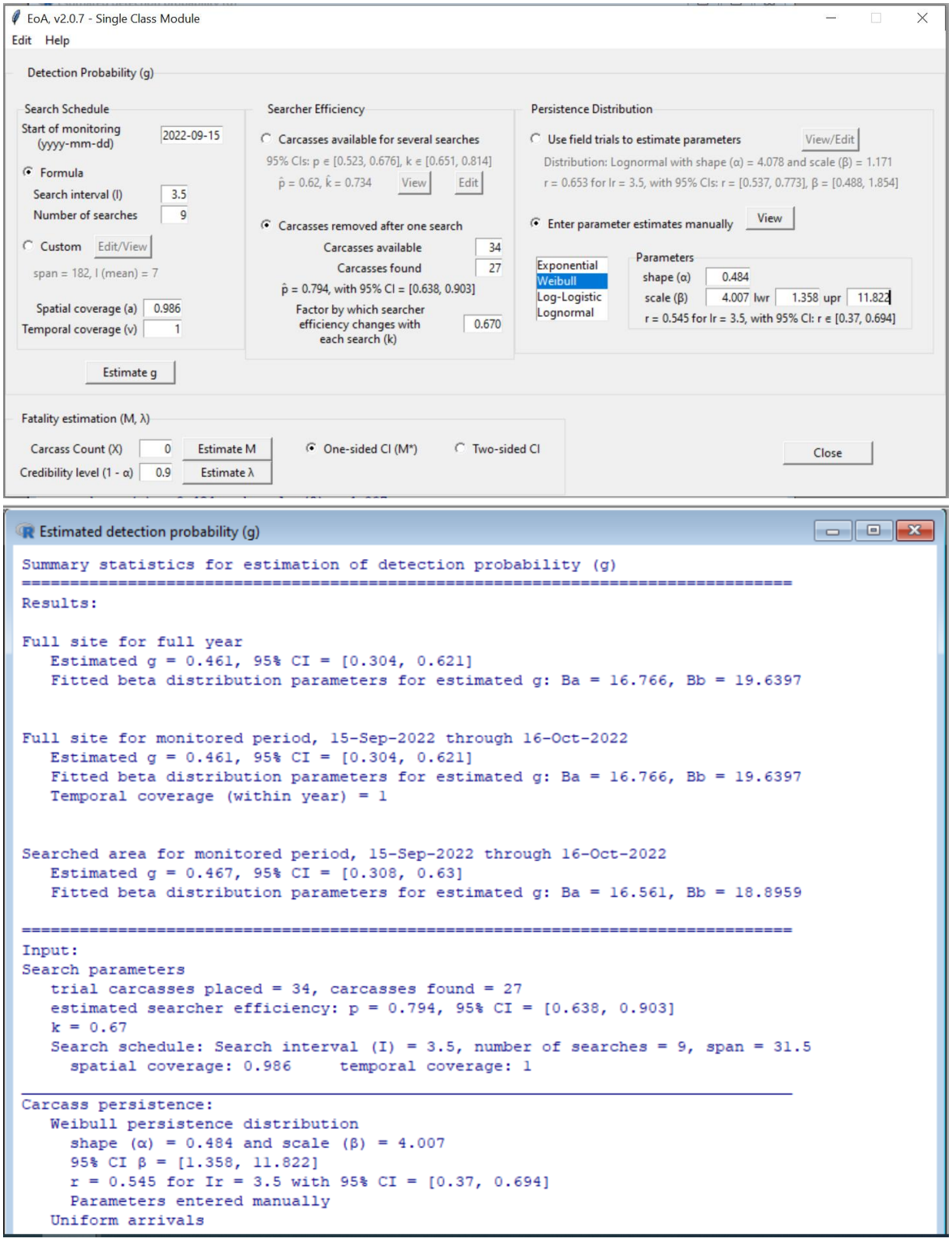




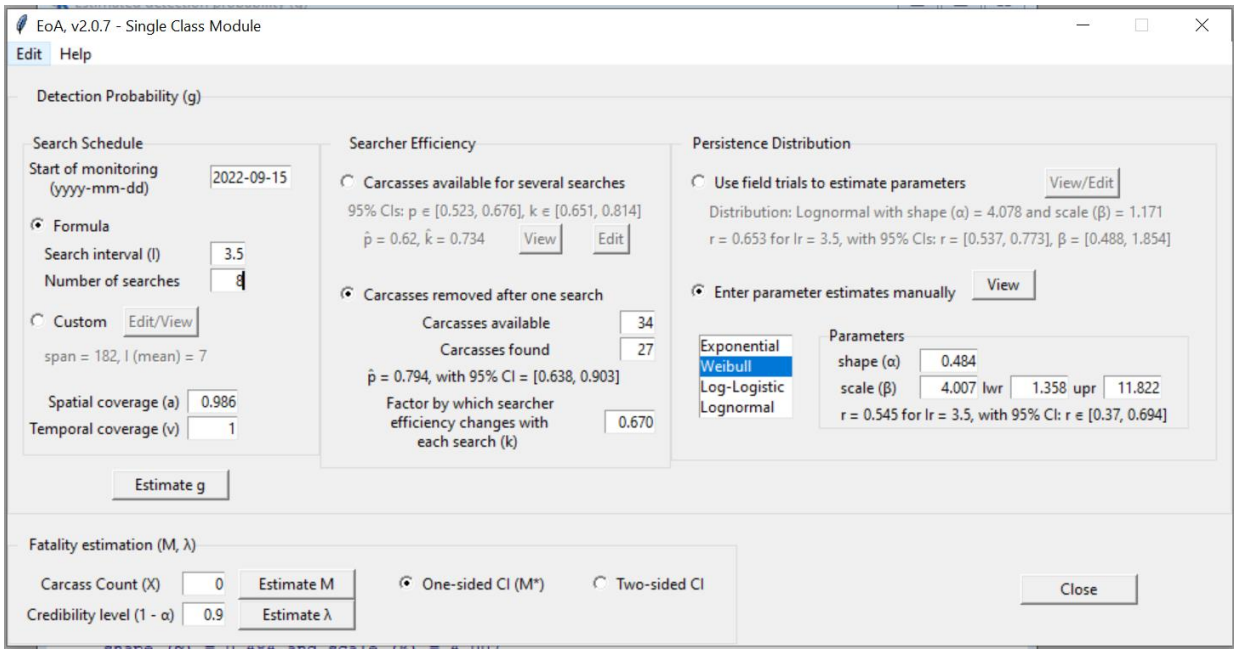
Appendix D11. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 2, 2022, 70-meter uncleared plot searches at two turbines, searched at a 3.5-day interval.

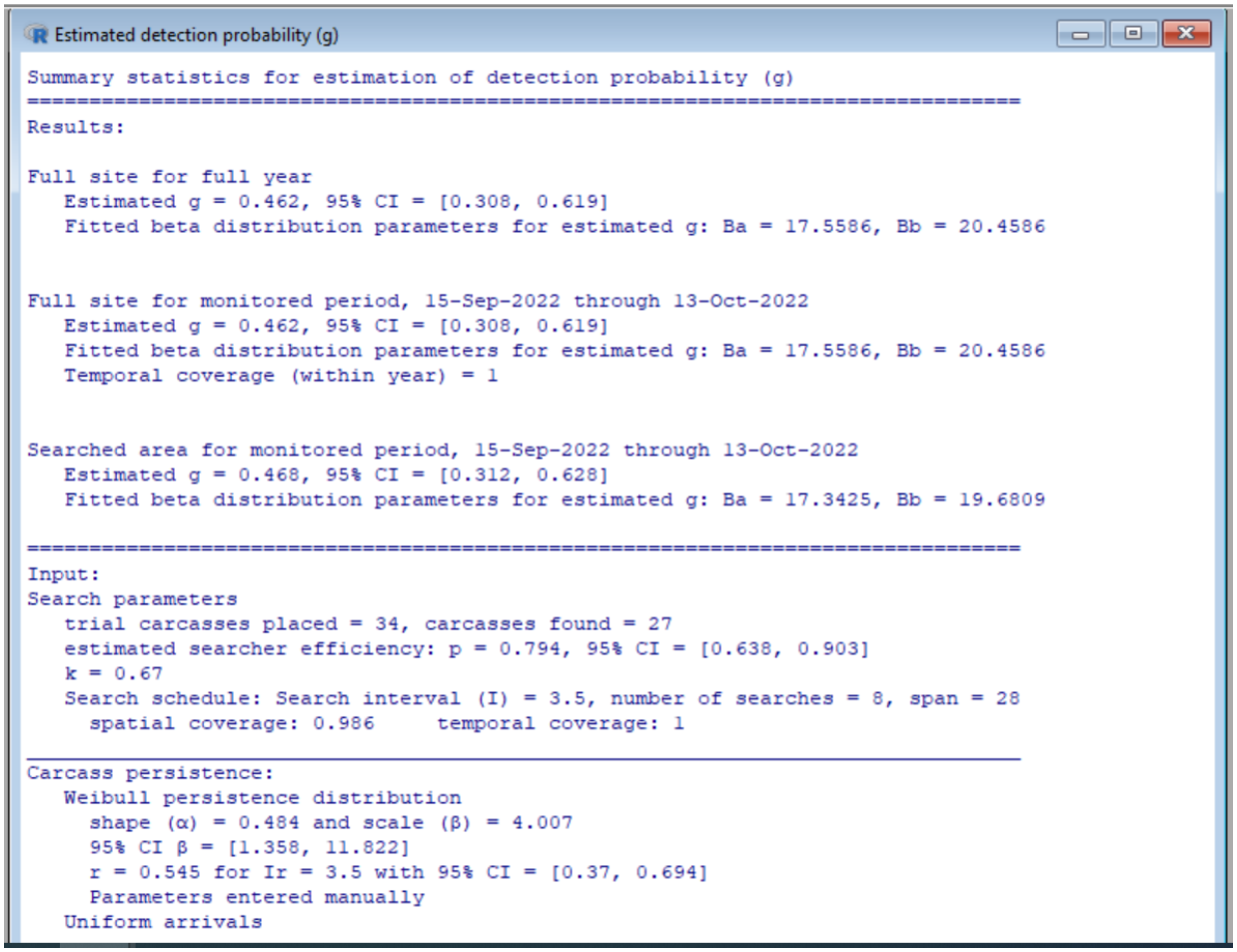


Appendix D12. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 3, 2022, 100-meter road and pad plot searches at 17 turbines, searched at a 7-day interval.

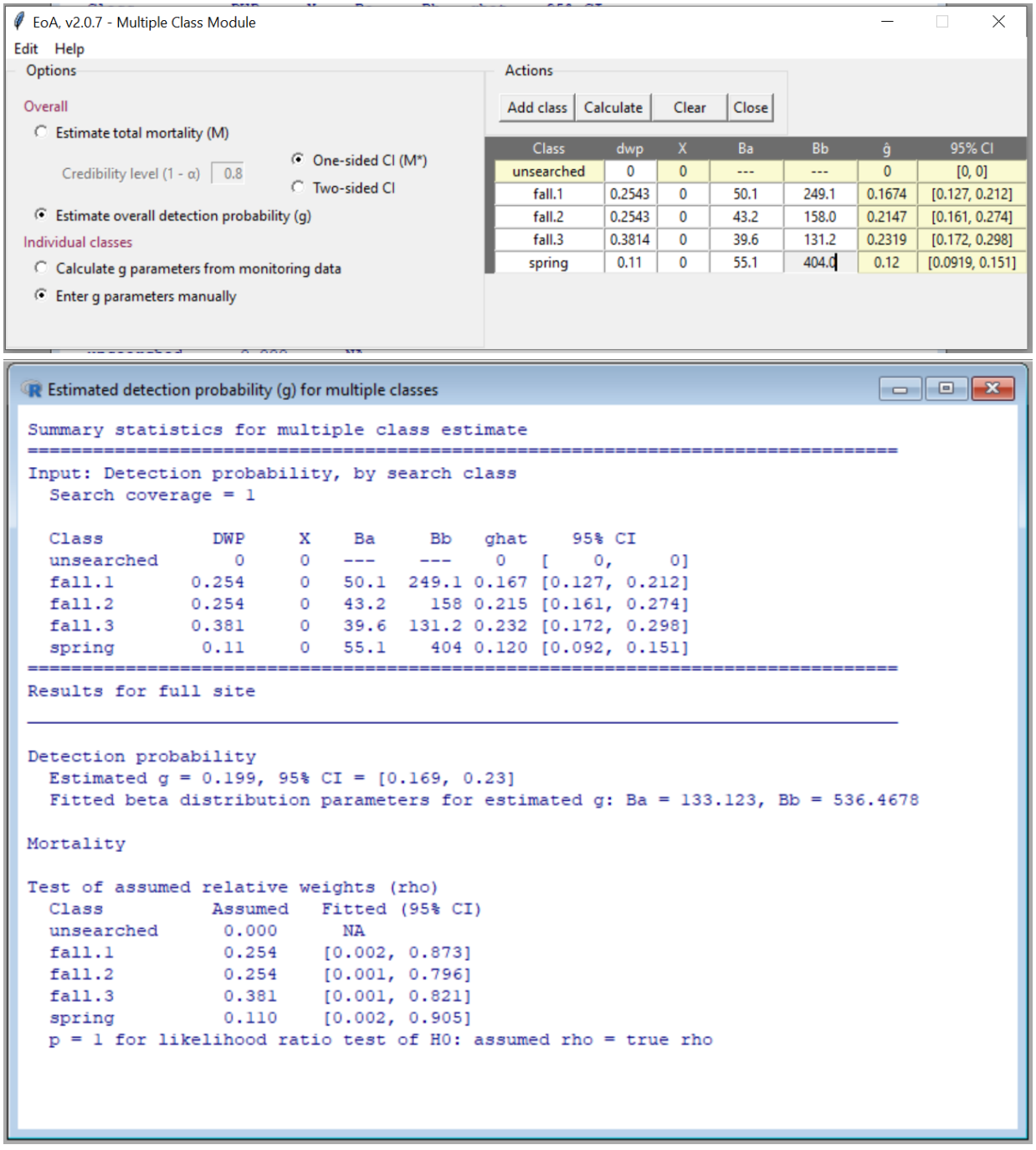


Appendix D13. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 3, 2022, 70-meter cleared plot searches at 11 turbines, searched at a 3.5-day interval.

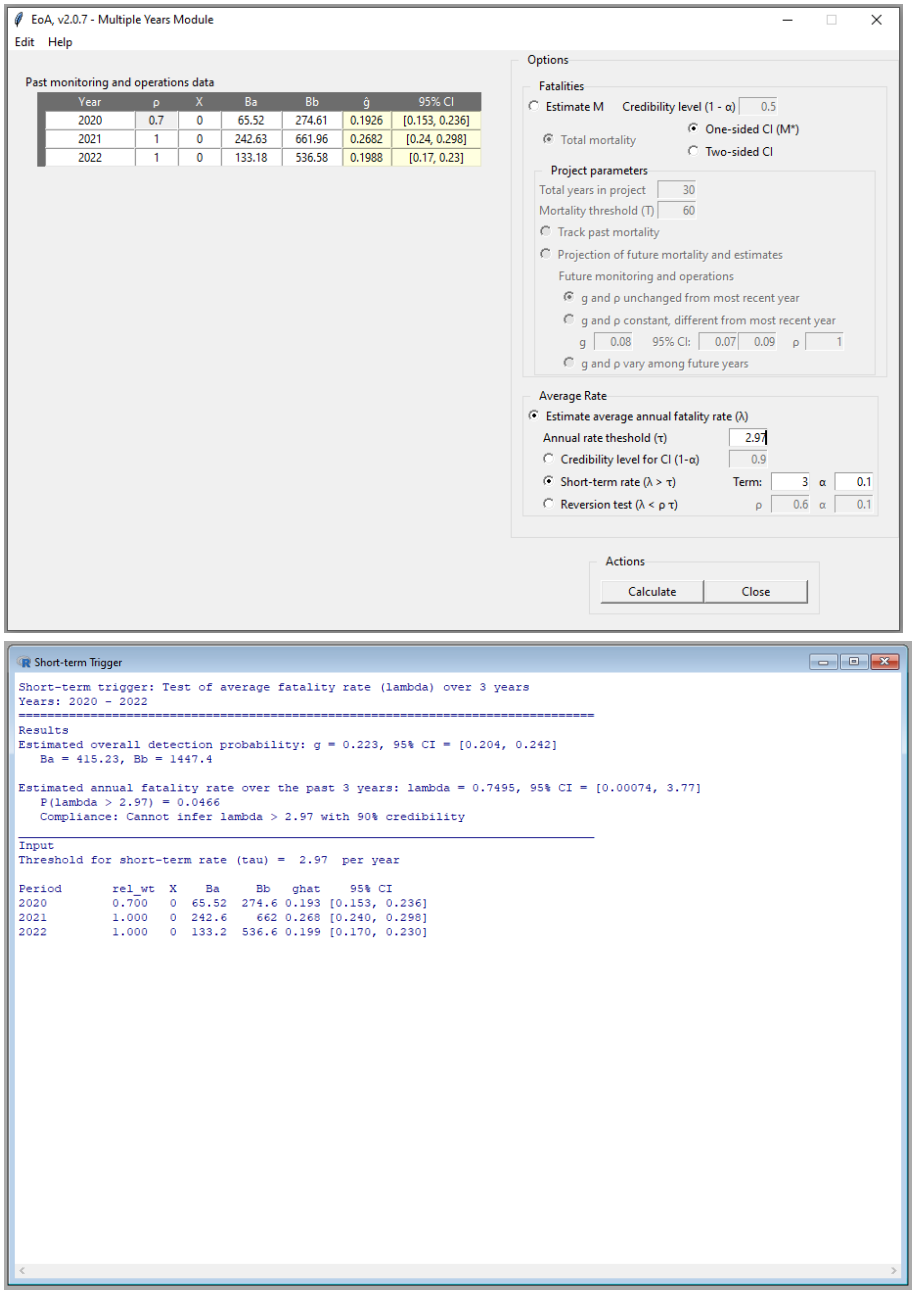




Appendix D14. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Single Class Module inputs for Fall 3, 2022, 70-meter uncleared plot searches at two turbines, searched at a 3.5-day interval.

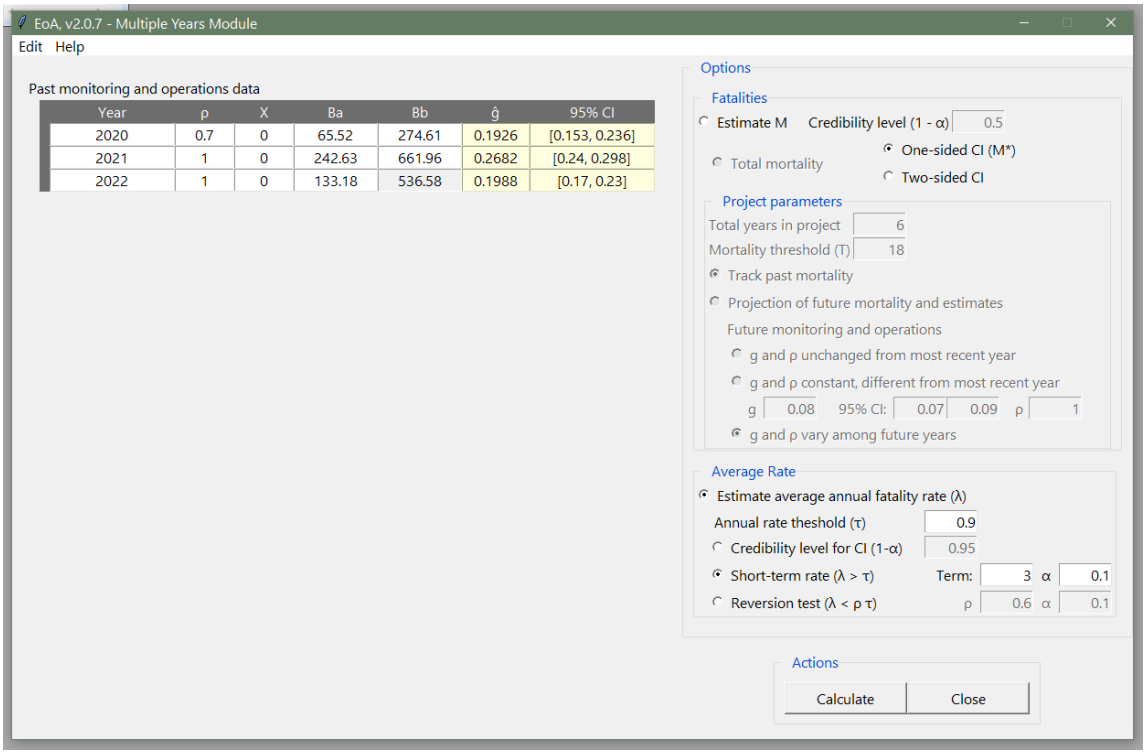


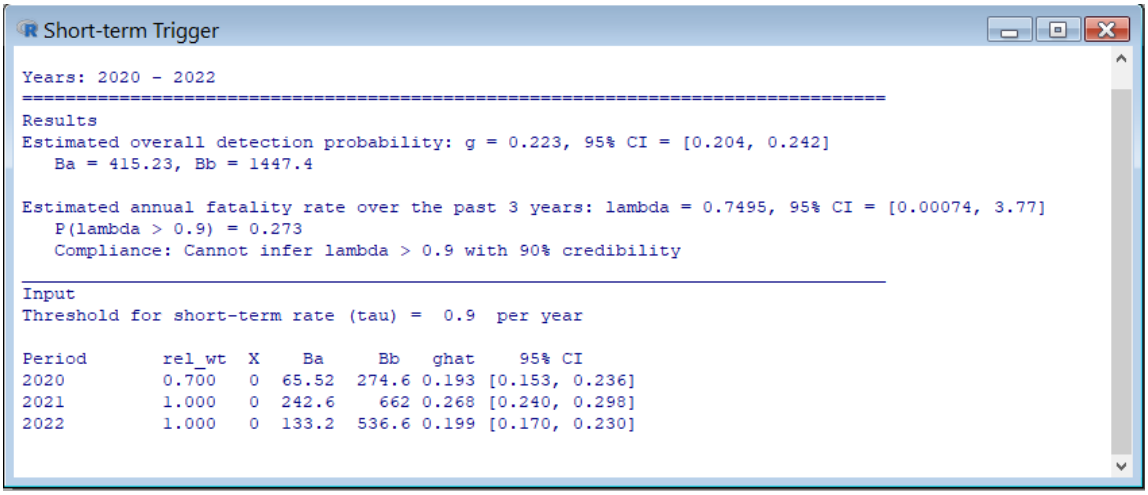
Appendix D15. Screen shot of Evidence of Absence (v2.0.7) graphical user interface, Multiple Class Module inputs for all plot types in 2022 (n = 30), searched at a 7-day interval for 100-meter road and pads, and a 3.5 day interval for 70-meter cleared and uncleared plots.



Appendix D16. Screen shot of Evidence of Absence (v2.0.7; EoA) graphical user interface (GUI), Multiple Years Module inputs 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 is equal to 2.7, the EoA GUI produces a "year-adjusted λ", by calculating the average λ over the number of input rows (years). 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, we would like to calculate the "ρ-adjusted λ". The GUI does not accommodate that calculation. The “ρ-adjusted λ”, 0.83, is equivalent to the "year-adjusted λ" (0.75 as seen in the output above) divided by ρ (2.7) times the number of years (3). The EoA GUI tests the short-term trigger by comparing that “year-adjusted λ” to the expected take rate (τ). We would like to test the "ρ-adjusted λ" against τ, but the GUI does not accommodate that test. However, we can obtain a correct p-value by adjusting τ to produce a “ρ-adjusted τ” for the particular multiple-year dataset at hand. For example, we calculate a “ρ-adjusted τ" by taking τ * sum(ρ) / (n rows of data) = 3.3 * 2.7 / 3 = 2.97 in the above example.





Appendix D17. Screen shot of Evidence of Absence (v2.0.7) graphical user interface (EoA GUI), Multiple Years Module inputs 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 that although the weight (ρ) column of the Multiple Years Module is equal to 2.7, the EoA GUI produces a "year-adjusted λ", by calculating the average λ over the number of input rows (years). 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, we would like to calculate the "ρ-adjusted λ". The GUI does not accommodate that calculation. The “ρ-adjusted λ”, 0.83, is equivalent to the "year-adjusted λ" (0.75 as seen in the output above) divided by ρ (2.7) times the number of years (3). The EoA GUI tests the short-term trigger by comparing that “year-adjusted λ” to expected take rate (τ). We would like to test the "ρ-adjusted λ" against τ, but the GUI does not accommodate that test. We can obtain a correct p-value by adjusting τ to produce a “ρ-adjusted τ” for the particular multiple-year data set at hand. For example, we calculate a “ρ-adjusted τ" by taking τ * sum(ρ) / (n rows of data) = 1.0 * 2.7 / 3 = 0.9 in the above example.