Draft Habitat Conservation Plan

MidAmerican Energy Company

Iowa Wind Energy Project Portfolio

Appendix D – Take Estimation Methods

December 12. 2018

NOTE: This version of Appendix D replaces the prior version of document that was released in error with the Draft HCP Federal Register Publication on August 29, 2018. This document contains calculations and methodology that reflect and support the take estimates listed in the MidAmerican Energy Company Iowa Wind Energy Project Portfolio Habitat Conservation Plan

ESTIMATING TAKE OF THE COVERED BAT SPECIES

Overview

A composite of three approaches was used to estimate the level of Covered Bat Species take that may result from operation of the turbines at the Projects. The species composition (SC) approach uses empirical monitoring data from the Projects to estimate mortality of all bat species, and then assigns a portion of that total mortality to covered bat species based on a species composition ratio estimated at the Projects or from a larger sample of fatalities. The Evidence of Absence (EoA) approach uses Project-specific effort data to estimate probability of discovering a fatality, averages that probability over the Projects after weighting by number of turbines, and inflates the total number of found fatalities by this probability. The Informed Evidence of Absence (IEoA) approach combines SC and EoA by informing the mortality prior distribution inherent in EoA with information from SC. The three methods are described briefly in the main text of this Appendix. Full details on all three methods can be found in the Addendums of this Appendix.

Estimating Bat Take

<u>Evidence of Absence</u>

The EoA method utilizes a statistical hierarchical model to estimate the actual number of fatalities from the number found and probability of discovery. The EoA estimator assumes the number of carcasses found during searches at a particular facility follows a binomial distribution, i.e.:

$$X \sim binomial(M, g)$$

where X is the total number of carcasses from all searches, M is the (unknown) number of carcasses of a covered species, and g is probability of discovering a carcass. Discovery probability g is the product of the probability that a turbine kills an individual bat, the probability that the carcass persists, and the probability that technicians detect the carcass during those searches. Discovery probability is estimated from the frequency of visits, searcher efficiency information, carcass persistence, and the proportion of the 1-D carcass distance distribution being searched.

The EoA method distinguished between estimating past and projecting future mortalities. When estimating past mortalities, the EoA method targets estimation of M, which is the number of mortalities that occurring at the monitored facilities during the monitoring years. When projecting future mortalities to set implementation and allowable take thresholds, the EoA method targets estimation of an annual rate (λ) which can be scaled to the entire permit term.

For estimation of past mortalities at monitored Projects, the hierarchical model used by EoA assumes the total number of covered species fatalities (M) follows an (improper) objective prior with probability mass function:

$$f(M) = \sqrt{M+1} - \sqrt{M}$$

for M = 0, 1, 2, ...∞. This objective prior closely approximates the Jeffery's prior for a Poisson distribution (i.e., $x^{-0.5}$), with the exception that finite mass is placed at zero.

When multiple Projects or time periods are involved in estimation, the EoA method assumes that the fleet-wide g follows a single beta prior distribution, i.e.:

$$g \sim beta(\alpha, \beta),$$

where α and β are estimated using an averaging process across periods (years) and facilities. Under this process, g values for Projects with multiple years of monitoring data are computed by averaging year-specific g's and computing α and β using the method of moments methodology. A fleet-wide g is then computed by weighting Project-specific g's by their number of turbines and averaging. The fleet-wide α and β parameters are then computed by method of moments.

Given prior distributions for *M* and g, a posterior distribution for the parameter of interest (*M*) was estimated using Bayesian methods. For expediency and transparency, the posterior distribution of *M* was estimated by Markov Chain Monte Carlo (MCMC) sampling in JAGS software (Plummer 2003). The point estimate reported here is the median of the posterior for *M*, while posterior credible intervals for *M* were computed as the lower and upper 5% quantiles from the posterior, which form a 90% credible interval. In this appendix and throughout the main text of the Habitat Conservation Plan (HCP), the median posterior estimates have been labeled P50, the upper endpoint of the 90% confidence interval (CI) has been labeled P90, and the posterior credible intervals have been simply called CIs.

For projecting future take by estimation of a rate, the EoA method assumes the rate of carcass deposition, *λ*, follows an (improper) continuous objective hyper-prior which closely approximates the discrete Jeffery's prior for a Poisson random variable, and also that *M* follows a Poisson distribution. We implemented an objective hyper-prior for λ to ensure close agreement between λ and *M*. For estimation of λ under EoA, we assumed:

$$\lambda \sim Pareto(0.00001, 0.25),$$
$$M \sim Poisson(\lambda).$$

Correlation between the *Pareto*(0.00001, 0.25) distribution and $x^{-0.5}$is 0.994.

Given the prior distributions for λ and g, the posterior distribution for λ was estimated by Bayesian MCMC sampling in JAGS software. The point estimate reported here is the median of the posterior for *λ,* while CIs for λ are lower and upper 5% quantiles from the posterior, which form a 90% Bayesian credible interval. Like *M*, we labeled the point estimate of λ P50, the upper endpoint of the 90% credible interval P90, and for simplicity call the credible intervals CIs.

Facilities under Construction

Prior to estimation by EoA, the observed number of carcasses was expanded to account for additional turbines in facilities under construction and not yet monitored covered by the permit. Found carcasses were expanded by computing the mean number of carcasses per monitored turbine over all facilities and time periods, and multiplying this mean rate by the number of un-built turbines. This procedure assumes the per-turbine fatality rate at facilities under construction equals the per-turbine fatality rate at monitored facilities[1]. In addition, this procedure assumes searcher efficiency, carcass removal, area correction, and search interval at facilities under construction was equal to the fleet-wide analogous quantity on monitored facilities. That is, the fleet-wide *g* was used for facilities under construction. The expanded number of carcasses was rounded to the nearest integer and used in the EoA method. In some cases (e.g., Indiana bat [INBA; *Myotis sodalis*]), the number of expansion carcasses was less than 0.5, the number rounded down to zero, and no carcasses were added to found carcasses to account for facilities under construction.

Species Composition:

Take estimation by the SC approach involved four steps. First, all bat mortality estimates on a per turbine basis were calculated for each Project and the entire fleet of Projects (Fleet)[2]. Second, the percent composition ratios for the Covered Bat Species were estimated from data collected at the Projects, or at the Projects plus other projects in Iowa that have published their data. Third, the estimated species composition ratios for each Covered Bat Species multiplied by the Fleet-wide all-bat mortality estimates and number of turbines estimated the take of each Covered species. Fourth, the estimated variance of the Fleet-wide take estimate was calculated taking into account variability from both the species composition ratios and the all-bat mortality estimates. Each of these four steps is described in separate sub-sections below, with additional details in Addendum 1.

All-Bat Mortality Estimates

All bat mortality estimates for each Project were developed from carcass counts, searcher efficiency, carcass persistence trials, and proportion of area searched (area correction) using the Huso estimator (Huso 2011, Huso et al. 2012). A full description of field and statistical methods is given in Project specific reports on post-construction monitoring (Bay et al. 2016, 2017). In summary, the Project specific area correction factors used a truncated weighted likelihood (TWL) method to estimate the proportion of the carcass location distribution searched (Bay et al. 2016, 2017). For the Fleet, mean all-bat fatalities per turbine was calculated by first averaging the annual estimates for the three facilities that conducted monitoring during both years, then weighting by number of turbines and

---

[1] MidAmerican Energy Company (MidAmerican or MidAmerican Energy) agreed with the United States Fish and Wildlife Service (USFWS) to update, if necessary, the take estimates once the studies at Ida Grove and O'Brien are complete in 2017.

[2] The range of INBA only includes eight Projects; thus, the number of turbines and all bat estimates in the Fleet differ for INBAs compared to the other Covered Species.

averaging across all of the Projects within the Covered Species' range. Variance of the Fleet-wide per-turbine estimate of all-bat mortality was computed using bootstrap methods (details in Addendum 1).

Species Composition Ratios

We estimated species composition ratios, the proportion of each Covered Species in the population of all bat carcasses, using Project specific monitoring data for three of the four Covered Species (INBA, tri-colored bat [TRBA; *Perimyotis subflavus*], and little brown bat [LBBA; *Myotis lucifugus*) and Project specific plus Iowa specific data for one Covered species (northern long-eared bat [NLEB; *M. septentrionalis*]). Iowa-specific data were included in the ratio estimate because no NLEB carcasses were found at the Projects during either monitoring year, and inclusion of additional data from Iowa likely improved estimation of the NLEB ratio.

We estimated all species composition ratios using a Bayesian method that assumed the underlying ratios followed the Jeffery's prior for a beta distribution, i.e., *beta*(0.5, 0.5). Assuming the number of a specific Cover Species carcasses (x) follows a binomial distribution with index equal to the total number of observed carcasses (n), the posterior distribution of the species ratio is *beta*(x+0.5, n-x+0.5). We estimated the composition ratio as the mean of the posterior, i.e.:

$$p = \frac{x+0.5}{n+1}.$$

We estimated the variance of p as the variance of the posterior, i.e.:

$$var(p) = \frac{(x+0.5)(n-x+0.5)}{(n+1)^2(n+2)}.$$

The Fleet-wide per turbine fatality estimate was multiplied by the estimated species composition ratio for Covered Species to obtain Fleet-wide per turbine fatality estimates for covered species. These per-turbine estimates were then multiplied by the number of turbines in the Fleet to estimate the total annual bat fatalities for each of the Covered Species (see Addendum 1 for additional details).

Different data sets were used to determine the species composition ratios for each Covered Bat Species because MidAmerican-specific data did not contain at least one fatality of all species. We desired at least one fatality of each Covered Species to improve accuracy of the ratio estimates.

Data on collision risk factors for migrating INBA and *Myotis* species in general) are currently limited. INBAs are assumed to occur in the vicinity of eight Projects during the active period. These eight Projects were generally located in the southern third of Iowa, excepting the extreme southwest. Monitoring efforts at five of the eight Projects within INBA range from March 16 to November 15 in 2015 yielded no INBA fatalities (Bay et al. 2016; Table 1). From March 16, 2016 to October 14, 2016, monitoring at two previously monitored Projects and at the remaining three previously unmonitored Projects yielded a single INBA (Bay et al. 2017; Table 1). Given one observed INBA fatality, it was reasonable to use Project-specific monitoring data to estimate percent composition for INBA that could be expected for the Projects within the Iowa INBA range. The empirical (non-Bayes) composition ratio for INBAs was approximately 0.09% (Table 1). After application of the Bayes methodology, the estimated of the proportion of INBAs in the population of dead bats is 0.128% (Table 1 and Table 3 of Addendum 1).

Table 1. Species Composition of Covered Bat Species and Other Carcasses Found During Post-Construction Monitoring at the Projects and Other Post-Construction Monitoring Studies in Iowa.

Project	Turbines	Number of Bat Carcasses					
		INBA	NLEB	LBBA	TRCA	Other Bats	Total
Adair (2015)[1]	76	0	0	0	0	54	54
Adams (2016)	64	0	0	0	4	189	193
Carroll (2015)	100	0	0	0	0	56	56
Century (2016)	145	0	0	1	2	185	188
Charles City (2016)	50	0	0	13	0	88	101
Eclipse (2015)[1]	87	0	0	0	1	71	72
Highland (2016)	214	0	0	1	7	367	375
Intrepid (2016)	122	0	0	0	0	188	188
Laurel (2016)[1]	52	0	0	1	0	95	96
Lundgren (2015)	107	0	0	26	7	264	297
Lundgren (2016)	107	0	0	4	2	241	247
Macksburg (2015)[1]	51	0	0	8	7	136	151
Macksburg (2016)[1]	51	1	0	6	3	180	190
Morning Light (2015)[1]	44	0	0	0	1	48	49
Pomeroy (2016)	184	0	0	0	1	124	125
Rolling Hills (2015)[1]	193	0	0	0	2	126	128
Rolling Hills (2016)[1]	193	0	0	1	5	247	253
Victory (2015)	66	0	0	0	0	21	21
Vienna I (2016)[1]	45	0	0	3	1	119	123
Vienna II (2016)[1]	19	0	0	2	1	50	53
Walnut (2015)	102	0	0	0	0	79	79
Wellsburg (2016)	60	0	0	7	1	161	169
MidAmerican Total		**1**	**0**	**73**	**45**	**3089**	**3208**
Percent		**0.09%[2]**	**0.00%**	**2.28%**	**1.40%**	**96.29%**	**100.00%**
Bayes Percent		**0.13%**	**-**	**2.29%**	**1.42%**	**-**	**-**
Other Iowa Facilities							
Barton I & II[3]		0	0	1	0	19	20
Crystal Lake II[4]		0	0	21	0	127	148
Pioneer Prairie (2011-2012)[5]		0	0	13	0	61	74
Pioneer Prairie (2013)[6]		0	2	6	0	75	83
Top of Iowa (2003)[7]		0	0	9	0	23	32
Top of Iowa (2004)[7]		0	0	9	1	36	46
Winnebago[8]		0	0	2	0	8	10
Other Iowa Total		0	2	61	1	349	413
MidAmerican + Iowa Total		**1**	**2**	**134**	**46**	**3438**	**3621**
Percent		**0.03%**	**0.055%**	**3.70%**	**1.27%**	**94.95%**	**100%**
Bayes Percent		**-**	**0.069%**	**-**	**-**	**-**	**-**

[1]Within INBA range; [2]Percentage within INBA range; [3]Derby et al. 2011; [4]Derby et al. 2010a; [5]Chodachek et al. 2012; [6]Chodachek et al. 2014; [7]Jain 2005; [8]Derby et al. 2010b

No fatalities of NLEB were found during monitoring at the Projects in 2015 or 2016. When combined with two NLEB fatalities observed in publicly available studies conducted in Iowa, about 0.055% of all bat fatalities reported in Iowa were NLEBs (Table 1).

Application of the Bayesian method increased this proportion to 0.069% (Table 1 and Table 3 of Addendum 1).

LBBA carcasses were found at two Projects in 2015 and at 10 Projects in 2016, allowing an estimate of composition ratio for this species to be calculated using MidAmerican-only data. MidAmerican's data estimate that the LBBA composed approximately 2.28% of all bat fatalities (Table 1). Application of the Bayesian method increased this proportion to 2.29% (Table 1 and Table 3 of Addendum 1).

TRBA carcasses were found at five Projects in 2015 and at 10 Projects in 2016, allowing an estimate of composition ratio for this species to be calculated using MidAmerican-only data. MidAmerican data estimate that the TRBA composed approximately 1.40% of all bat fatalities (Table 1). Application of the Bayesian method increased this proportion to 1.42% (Table 1 and Table 3 of Addendum 1).

<u>Informed Evidence of Absence</u>

The IEoA approach uses estimates of covered species mortality from the SC approach to inform the prior distributions of both M and λ in the EoA approach. Because the past mortality estimate, M, equals an integer and could theoretically equal 0, a truncated normal prior distribution was assumed, i.e.:

$$M \sim truncNormal(\mu, \sigma^2).$$

The *truncNormal* distribution was a discretized and (left) truncated normal density and contained mass on the integers 0, 1, 2, …, M_{max}, with M_{max} set large enough to be well above the 90% upper credible bound. Mean and variance of the truncated normal (μ and σ^2) were the estimated mean and variance of Covered Species annual fatality rate produced by the SC approach.

The mortality rate estimate, λ, could equal any real number but theoretically should be strictly greater than zero. Consequently, a gamma prior distribution was assumed when computing an informed estimate of λ. The informed prior distribution for λ was:

$$\lambda \sim gamma(\mu, \sigma^2)$$

where μ and σ^2 were the estimated mean and variance of annual fatality rate produced by the SC approach.

Other than changing the prior distributions for M and λ, the IEoA and EoA approaches are identical. In particular, g and parameters of its beta distribution were computed in the same way.

Simulations have shown that when all assumptions hold both SC and EoA estimates are unbiased and that their precision estimates are valid. Amalgamating the estimates from these two approaches increases the amount of information available and increases both accuracy and precision; thus, the IEoA was the chosen method to determine the final take estimates.

Bat Take Results

Past Mortality Estimates

Estimates of *M* by all three analytical methods appear in Table 2. All SC point estimates exceed EoA (obj) point estimates, with greater agreement for the larger bat species (LBBA and TRBA). Except for NLBA, all SC point estimates were within the 90% CI produced by EoA (obj). While the SC point estimate for NLBA exceeded the EoA CI, the CI for the SC estimate was wide and overlapped the CI for EoA (NLBA 90% CI for EoA = [0,19]; 90% CI for SC = [0,64]). Based on these observations, we concluded substantial similarity of the objective EoA and SC estimates.

Based on IEoA (normal), estimated take for INBA was 19 bats (90% CI [5, 39]), 13 NLEBs (90% CI [1, 37]), 987 LBBAs (90% CI [844, 1,134]), and 597 TRBAs (90% CI [493, 709]; Table 2). Except for NLBAs, the IEoA estimated 90% CI was smaller than the interval estimated by EoA. The NLBA IEoA CI was wide due to high uncertainty in the SC estimate for this species.

Table 2. Past mortality (M) estimated by EoA assuming an objective prior ('EoA (obj)'), species composition, and IEoA assuming a truncated normal prior ('IEoA (normal)').

Method	INBA	NLBA	LBBA	TRBA
EoA (obj)	16 (3,52)	2 (0,19)	954 (7901,1133)	562.5 (439,716)
Species Comp	19.96 (0,47.18)	31.3 (0,64.18)	1038.62 (801.11,1276.12)	642.95 (466.79,819.12)
IEoA (normal)	19 (5,39)	13 (1,37)	987 (844,1134)	597 (493,709)

Mortality Rate Estimates

Estimates of λ by all three analytical methods appear in Table 3 and generally mirrored estimates of *M* in Table 2. Due to similarities in the priors assumed for λ and *M*, all SC point estimates again exceeded the corresponding EoA (obj) point estimates. Except for NLBAs, all SC point estimates were within the 90% CI produced by EoA (obj), and the SC NLBA CI overlapped the CI for EoA (NLBA 90% CI for EoA = [0.03,13.9]; 90% CI for SC = [0,64.18]). Based on these observations, we again concluded substantial similarity of the objective EoA and SC estimates.

Based on IEoA (gamma), estimated take rate for INBAs was 14.9 bats per year (90% CI [3.69,38.47]), 13.19 NLEBs per year (90% CI [3.48, 32.67]), 984.82 LBBAs per year (90% CI [850.94, 1,133.28]), and 596.11 TRBAs per year (90% CI [497.08, 706.36]; Table 3). Except for NLBAs, the IEoA estimated 90% CI was smaller than the interval estimated by EoA. The NLBA IEoA CI was wide due to high uncertainty in the SC estimate for this species.

Table 3. Annual estimated fatality rates (λ) estimated by EoA assuming an objective prior ('EoA (obj)'), species composition, and IEoA assuming a gamma prior ('IEoA (gamma)').

Method	INBA	NLBA	LBBA	TRBA
EoA (obj)	10.01 (1.01,43.5)	1.48 (0.3,13.99)	955.62 (790.36,1132.21)	561.80 (438,710.73)
Species Composition	19.96 (0,47.18)	31.30 (0,64.18)	1038.62 (801.11,1276.12)	642.95 (466.79,819.12)
IEoA (gamma)	14.90 (3.69,38.47)	13.19 (3.48,32.67)	984.82 (850.94,1133.28)	596.11 (497.08,706.36)

Estimating Bald Eagle Take

In order to evaluate risk and predict levels of take of bald eagles (*Haliaeetus leucocephalus*) at the Projects, a number of different take prediction methods were evaluated. Of these, three take prediction methods were considered in detail: (1) the United States Fish and Wildlife Service (USFWS) *Eagle Conservation Plan Guidance* (ECPG; USFWS 2012, 2013) Bayesian collision risk model (including a prediction using MidAmerican-specific data collected on bald eagle use and a prediction using MidAmerican data on both eagle use and fatalities), (2) a MidAmerican -specific collision risk model developed from use and fatality data collected at the Projects, and (3) an EoA estimate of fatality rates based on fatality monitoring data collected at the Projects. Each method incorporates post-construction eagle fatality data collected at the Projects.

Post-Construction Monitoring Surveys

Post-construction monitoring surveys designed to detect eagle carcasses were conducted once every four weeks from November 16, 2014, through May 31, 2015, at the first set of nine facilities: Walnut, Rolling Hills, Adair, Eclipse, Morning Light, Macksburg, Carroll, Victory, and Lundgren. The surveys were conducted at all turbines and split into three treatments: 70% of turbines were searched using visual scans, 15% of turbines were searched using transects 20 meters (m; 66 feet [ft]) apart, and 15% of surveys were searched using transect 40 m (131 ft) apart. Due to landowner concerns, all eagle surveys were conducted using eagle scans from April 22 – May 15, 2015.

From November 15, 2015, to February 29, 2016, visual scans for eagle carcasses were conducted at all turbines at the nine facilities surveyed in 2015/2016, as well as the second set of nine additional facilities: Charles City, Wellsburg, Laurel, Vienna I, Vienna II, Century, Pomeroy, Intrepid, and Highland. Visual scans for eagle carcasses were conducted at the second set of nine facilities for a second winter from November 15, 2016, to March 15, 2017.

Visual Scans

Visual scans were conducted within a 100-m (328-ft) radius plot centered on the turbine. Searchers stood at the edge of the turbine pad at each of the four cardinal directions, and scanned for eagle carcasses using binoculars.

Transect Surveys

Transect surveys were conducted within 200 m by 200 m (656 ft by 656 ft) square plots centered on the turbine (Figure 1). Searchers walked transects that were placed either 40 m or 20 m (131ft or 66 ft) apart while scanning the area on both sides of the transect for casualties.

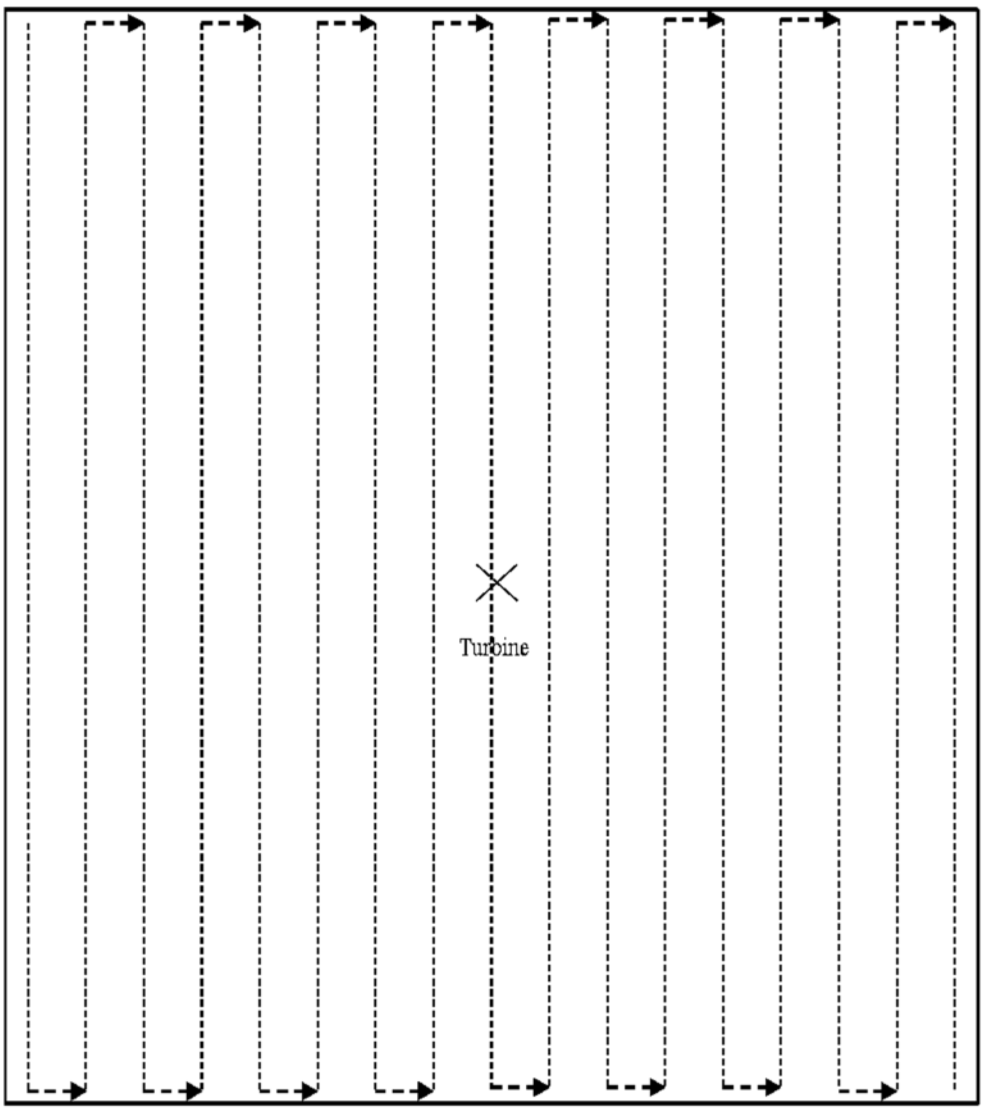

Figure 1. Schematic of a Full Survey Plot (Not to Scale). Transects on Half the Plots were Placed 40 Meters (131 Feet) Apart, while Transects on the Remaining Plots were Placed 20 Meters (66 Feet) Apart.

Estimated Bald Eagle Take

Method 1: Eagle Conservation Plan Guidance Bayesian Collision Risk Model

The first method MidAmerican used to predict the number of annual bald eagle fatalities at the Projects is the Bayesian collision risk model recommended by USFWS in the 2012 ECPG Technical Appendices (USFWS 2012) and the final ECPG (USFWS 2013). The USFWS Bayesian model predicts fatality rates at a wind facility as a function of eagle use of the Project area (exposure rate) measured by point-count surveys, the factor that scales the exposure rate to the amount of time and area in which eagles are at risk of collision based on facility characteristics (expansion factor), and the rate that an eagle would collide with a turbine per exposure within the turbine hazardous area (collision rate; USFWS 2013). The annual fatality rate is modeled in the Bayesian framework and assumes a relationship between eagle exposure, collision rate, and eagle fatalities (USFWS 2013). Bayesian models use existing information to estimate a starting point for the statistical distributions for the variables of interest (called the prior probability distribution) and then uses new data to update the distribution (called the posterior probability distribution). The new data used to update the posterior probability distributions in this model comes from eagle use and fatality monitoring data that were collected between December 2014 and March 2017 at MidAmerican's Projects. Variables incorporated into the model are defined in Table 4.

Table 4. Variables Used in the Bayesian Collision Risk Model.

Symbol	Name	Description (Units)
F	Eagle Fatalities	Annual eagle fatalities from turbine collisions
λ	Exposure Rate	Eagle-minutes flying within the facility footprint (in proximity to turbine hazards) per hour x square kilometer (km^2)
ε	Expansion Factor	Product of daylight hours and total hazardous area hour x km^2
C	Collision Rate	The rate of an eagle colliding with a turbine per exposure
k	Eagle Minutes	Number of minutes that eagles were observed flying within 800 m (2,625 feet) and below 200 m during survey point counts
δ	Turbine Hazardous Area	Total area within one rotor radius of a turbine (km^2)
n	Number of point counts	The number of point count periods surveyed
T	Daylight Hours	Total hours of daylight (units = hours)
n_{tur}	Number of turbines	Number of turbines in the project

Exposure Rate

Exposure rate (λ), as defined by the USFWS (2013), is the expected number of flight minutes below 200 m per daylight hour across the surveyed area (in kilometers squared [km^2]). The USFWS prior distribution for exposure rate was derived using data from wind energy projects in the western United States (U.S.) under USFWS review and from a study by Whitfield (2009). The prior distribution is intended to model exposure rates for any wind energy facility. The USFWS defines the prior distribution for exposure rate as:

$\text{Prior } \lambda \sim \text{Gamma}(\alpha, \beta)$, with shape and rate parameters $\alpha =$ 0.97 and β = 2.76.

Eagle exposure data from the MidAmerican Projects were then used to estimate the parameters for the posterior distribution. By assuming the exposure minutes follow a Poisson distribution with rate parameter λ, the posterior distribution for exposure rate is:

$$\text{Posterior } \lambda \sim \text{Gamma}\left(\alpha + \sum_{i=1}^{n} k_i,\ \beta + n\right)$$

where $\sum k_i$ is the total observed eagle minutes, n is the number of trials, and α and β are from the prior distribution. The number of trials is the number of hours · km^2 that were conducted in point count surveys.

The exposure rate for bald eagles was estimated for each season using data collected at point count locations within the Projects' boundaries. Additional point count data were collected outside of Project boundaries but were not used in this analysis as data were not collected in the spring, summer and early fall . A total of 23, 11, 65, and 908 bald eagle flight minutes were observed during spring, summer, fall, and winter, respectively (Table 5). Seasons were defined as spring (March 16 – May 31), summer (June 1 – July 31), fall (August 1 – October 31), and winter (November 1 – March 15). Data collected from December 1, 2014 to March 31, 2015, and from November 15, 2015 to February 29, 2016, were combined to estimate the exposure rate for winter.

The posterior distributions for exposure rate are *Gamma (23.97, 990.51),* with mean 0.024 eagle flight minutes observed per hour of survey in a single km^2 for the baseline data in the spring, *Gamma (11.97, 1,556.33),* with mean 0.008 in the summer, *Gamma (65.97, 1,360.30),* with mean 0.048 in the fall, and *Gamma (908.97, 3,357.24),* with mean 0.271 in the winter.

Table 5. Estimated Exposure Rate (λ) by Season from Bald Eagle Observations Made during Point Count Surveys at the MidAmerican Energy Company's Facilities.

Variable	Spring	Summer	Fall	Winter
1) Number of surveys	492	775	676	1,669
2) Average length of surveys (hours)	1	1	1	1
3) Survey hours	491.3	772.7	675.2	1,668.0
4) Survey radius (m)	800	800	800	800
5) Recorded flight minutes below 200 m at points	23	11	65	908
6) Eagle flight minutes (α α': Line 5 + α α)	23.97	11.97	65.97	908.97
7) Effort (β β'; survey hours x km^2 of area surveyed+β β)	990.51	1,556.33	1,360.30	3,357.24
8) Mean exposure rate (Line 6 / line 7)	0.024	0.008	0.048	0.271

<u>Expansion Factor</u>

The expansion factor (ε) is used to scale the per unit fatality rate (fatalities per hour km^2) to daylight hours and total hazardous area (km^2) within the Project area. The expansion factor is:

$$\varepsilon = \tau \sum_{i=1}^{n} \delta_i,$$

where n is the number of turbines, and is δ the circular area (2-dimensional hazardous area) centered at the base of a turbine having radius equal to the rotor-swept radius of the turbine).

The sunrise and sunset times for each facility were used to calculate the daylight hours at the Projects (U.S. Naval Observatory 2016). The expansion factor for each facility was calculated based on the daylight hours, number of turbines, and the rotor radius. The overall expansion factor for the MidAmerican Fleet was calculated as the sum of the expansion factors from the facilities. The expansion factors for the MidAmerican Fleet were 16,194; 14,207; 17,790; and 20,293 for spring, summer, fall, and winter, respectively. The expansion factors for each facility in the MidAmerican Fleet are given in Table 6b.

Table 6a. Expansion Factor for Facilities in the MidAmerican Energy Company Fleet during Post-Construction Monitoring.

Facility	Number of Turbines	Rotor Diameter (m)	Hazardous Area Per Turbine (km^2)	Daylight Hours				Expansion Factor			
				Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Intrepid I	107	70.5	0.0039	1,049	921	1,151	1,349	438	385	481	564
Century I	100	70.5	0.0039	1,049	921	1,151	1,349	409	360	449	527
Intrepid II	15	61	0.0029	1,049	921	1,151	1,349	46	40	50	59
Century II	35	61	0.0029	1,049	921	1,151	1,349	107	94	118	138
Victory	66	71	0.0040	1,047	918	1,150	1,354	274	240	301	354
Pomeroy I	82	71	0.0040	1,049	921	1,151	1,349	341	299	374	438
Pomeroy II	50	71	0.0040	1,049	921	1,151	1,349	208	182	228	267
Century III	10	71	0.0040	1,049	921	1,151	1,349	42	36	46	53
Charles City	50	71	0.0040	1,051	925	1,152	1,344	208	183	228	266
Pomeroy III	34	71	0.0040	1,049	921	1,151	1,349	141	124	155	182
Pomeroy IIIa	5	71	0.0040	1,049	921	1,151	1,349	21	18	23	27
Adair	76	93	0.0068	1,044	914	1,149	1,360	539	472	593	702
Walnut I	67	71	0.0040	1,043	913	1,149	1,362	277	242	305	361
Walnut II	35	71	0.0040	1,043	913	1,149	1,362	145	126	159	189
Carroll	100	71	0.0040	1,047	918	1,150	1,354	414	364	455	536
Pomeroy IV	13	101	0.0080	1,049	921	1,151	1,349	109	96	120	140
Rolling Hills	193	101	0.0080	1,043	912	1,149	1,363	1,613	1,411	1,777	2,108
Laurel	52	101	0.0080	1,046	917	1,150	1,356	436	382	479	565
Eclipse	87	108	0.0092	1,045	915	1,150	1,359	833	729	916	1,083
Morning Light	44	108	0.0092	1,044	914	1,149	1,360	421	368	463	548
Vienna I	45	108	0.0092	1,047	919	1,150	1,353	432	379	474	558
Vienna II	19	108	0.0092	1,047	919	1,150	1,353	182	160	200	236
Highland	214	108	0.0092	1,051	925	1,152	1,343	2,061	1,813	2,258	2,633
Lundgren	107	108	0.0092	1,048	920	1,151	1,351	1,027	902	1,128	1,324
Macksburg	51	108	0.0092	1,043	912	1,149	1,363	487	426	537	637
Wellsburg	60	108	0.0092	1,048	920	1,151	1,351	576	506	632	742

Table 6b. Expansion Factor for Facilities in the MidAmerican Energy Company Fleet for Bald Eagle Fatality Predictions.

Facility	Number of Turbines	Rotor Diameter (m)	Hazardous Area Per Turbine (km^2)	Daylight Hours				Expansion Factor			
				Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Intrepid I	107	82.5	0.0053	1,049	921	1,151	1,349	600	527	658	772
Century I	100	82.5	0.0053	1,049	921	1,151	1,349	561	492	615	721
Intrepid II	15	61	0.0029	1,049	921	1,151	1,349	46	40	50	59
Century II	35	61	0.0029	1,049	921	1,151	1,349	107	94	118	138
Victory	66	87	0.0059	1,047	918	1,150	1,354	411	360	451	531
Iowa State Fair	1	39	0.0012	1,045	915	1,150	1,359	1	1	1	2
Pomeroy I	82	87	0.0059	1,049	921	1,151	1,349	511	449	561	657
Pomeroy II	50	87	0.0059	1,049	921	1,151	1,349	312	274	342	401
Century III	10	87	0.0059	1,049	921	1,151	1,349	62	55	68	80
Charles City	50	87	0.0059	1,051	925	1,152	1,344	312	275	342	399
Pomeroy III	34	87	0.0059	1,049	921	1,151	1,349	212	186	233	273
Pomeroy IIIa	5	87	0.0059	1,049	921	1,151	1,349	31	27	34	40
Adair	76	93	0.0068	1,044	914	1,149	1,360	539	472	593	702
Walnut I	67	87	0.0059	1,043	913	1,149	1,362	416	364	458	543
Walnut II	35	87	0.0059	1,043	913	1,149	1,362	217	190	239	283
Carroll	100	87	0.0059	1,047	918	1,150	1,354	622	546	684	805
Pomeroy IV	13	101	0.0080	1,049	921	1,151	1,349	109	96	120	140
Rolling Hills	193	101	0.0080	1,043	912	1,149	1,363	1,613	1,411	1,777	2,108
Laurel	52	101	0.0080	1,046	917	1,150	1,356	436	382	479	565
Eclipse	87	108	0.0092	1,045	915	1,150	1,359	833	729	916	1,083
Morning Light	44	108	0.0092	1,044	914	1,149	1,360	421	368	463	548
Vienna I	45	108	0.0092	1,047	919	1,150	1,353	432	379	474	558
Vienna II	19	108	0.0092	1,047	919	1,150	1,353	182	160	200	236
Highland	214	108	0.0092	1,051	925	1,152	1,343	2,061	1,813	2,258	2,633
Lundgren	107	108	0.0092	1,048	920	1,151	1,351	1,027	902	1,128	1,324
Macksburg	51	108	0.0092	1,043	912	1,149	1,363	487	426	537	637
Wellsburg	60	108	0.0092	1,048	920	1,151	1,351	576	506	632	742
Adams	64	108	0.0092	1,042	911	1,149	1,365	611	534	674	800
Ida Grove Xa	14	100	0.0079	1,048	920	1,151	1,351	115	101	127	149
Ida Grove Xb	120	116	0.0106	1,048	920	1,151	1,351	1,329	1,167	1,459	1,713
O'Brian	104	108	0.0092	1,051	925	1,152	1,343	1,001	881	1,097	1,280

Collision Rate

The collision rate, *C*, is defined as the rate at which an eagle would collide with a turbine per exposure in the hazardous area, where all collisions are considered fatal. The prior distribution for collision rate was developed by the USFWS using the four fatality studies that Whitfield (2009) reported in a study of avoidance rates at wind energy projects in the western U.S. The Beta distribution is intended to model collision rates across all sites considered for prediction of annual eagle fatalities. The USFWS collision rate prior distribution is given as:

$$\text{Prior C} \sim \text{Beta}(v, v') \text{ with parameters } v=2.31 \text{ and } v'=396.69.$$

Post-construction monitoring data are used to update the collision rate prior distribution and estimate parameters of the posterior distribution. Assuming that observed fatalities follow a binomial distribution with rate *C*, the posterior distribution of rate *C* is a Beta distribution (Gelman et al. 1995) and is given as:

$$\text{Posterior C} \sim \text{Beta}(v + \text{f}, v' + \text{g} - \text{f}),$$

where *f* is the number of fatalities estimated from post-construction monitoring, g is the estimated number of exposure events, and *v* and *v´* are from the prior distribution (USFWS 2013, ECPG Appendix D). The posterior distribution can become the prior distribution as additional data collected from post-construction monitoring become available.

Annual bald eagle fatality rates at the Projects were predicted using the Bayesian collision risk model with collision rate prior distribution developed by the USFWS and the collision rate posterior distribution from the MidAmerican eagle use and fatality studies (Simon et al. 2016; Bay et al. 2016, 2017). The mean collision rate from the collision rate prior distribution was 0.00579 (Table 7).

Table 7. Collision Rates (C) for Bald Eagles.

Variable	Collision Rate Prior	First Collision Rate Posterior Distribution
Prior fatalities (v)	2.31	2.31
Prior exposure events not resulting in fatality (v')	396.69	396.69
Estimated number of fatalities during post-construction monitoring (f)	NA	5.00
Estimated number of exposures during post-construction monitoring (g)	NA	8,923.32
Posterior fatalities (v + f)	NA	7.31
Posterior exposure events not resulting in fatality (v' + g)	NA	9,315.01
Mean collision rate	0.00579	0.00078

To obtain the collision rate posterior distribution, the number of bald eagle fatalities and the number of exposure events that did not result in a fatality were estimated. Post-construction monitoring surveys were conducted at the first set of nine facilities from December 4, 2014 to May 15, 2015, and again from November 15, 2015, to March 15, 2016. Additionally, for purposes of these calculations, post-construction monitoring was conducted at the second-set of nine facilities from November 16, 2015 to

May 15, 2016, and again from November 16, 2016 to March 15, 2017[3]. At these 18 Projects, five bald eagle fatalities were reported during standardized carcass searches. One eagle found at Charles City on October 22, 2016, was excluded from analysis as it was found outside of the survey period, and one eagle found on March 7, 2017, at the Highland facility was excluded because it was found outside of the search area. Thus, three bald eagle fatalities were included in fatality rate estimation. However, the overall probability that a bald eagle carcass was both available to be found and detected at a facility during monitoring was not 100% due to carcass removal by scavengers, imperfect searcher detection rates, and the possibility that bald eagles may have fallen outside of the plots searched. Therefore, a multi-site EoA approach (Dalthorp et al. 2014) was used to determine, with a 50% probability, the maximum number of bald eagle fatalities at the Projects. The site-wide probability that a carcass is both available and detected was estimated using (Bay et al. 2016, 2017):

1. carcass persistence rates, expressed as the estimated average probability that a carcass was expected to remain in the study area and be available for detection;
2. searcher efficiency, expressed as the proportion of planted carcasses found by searchers during searcher efficiency trials;
3. the interval between carcass searches; and
4. a density-weighted correction for bald eagles that fell outside of the search area, based on visible area within 100 m of turbines at each facility.

Estimation of Carcass Persistence Rates

To estimate the length of time that eagle carcasses might persist and be available to be found during searches at Project turbines, a number of different types of non-eagle carcasses were used. Initially, surrogates for eagle carcasses consisted of adult ring-necked pheasants (*Colchicus phasianus*) and/or adult mallards (*Anas platyrhynchos*; Bay et al. 2016, 2017). In addition, if found during fatality searches, remains of intact diurnal raptor, owl, and vulture carcasses were marked for carcass persistence trials and observed in the same manner as the surrogate species. The number of observed raptor carcasses found during the first winter and spring was insufficient to allow for the calculation of an accurate raptor carcass persistence rate. MidAmerican conferred with the USFWS to obtain additional raptor carcasses to be used to test differences in carcass persistence rates between the surrogate species and actual raptors. The USFWS Rock Island Field Office had a source of raptor carcasses available from the O'Hare International Airport, so in addition, the USFWS provided MidAmerican with various raptor species that were used in the trials at the 18 facilities between November 15, 2015, and May 15, 2016, and again from November 16, 2016, to March 15, 2017. In total, 114 diurnal raptor, nine vulture, and four owl carcasses were monitored at the 18 facilities for 45-60 days. Previous results from other studies have shown that raptor carcasses last much longer than the standard surrogates, and particularly gamebirds such as pheasants (Urquhart et al. 2015, Hallingstad

[3] Post-construction monitoring is also ongoing at one project that reached commercial operations in January 2016 (Adams) and two projects that reached commercial operation in December 2016 (Ida Grove and O'Brien). As data are not yet available from these ongoing studies, they have not been included in these calculations. MidAmerican will update these calculations with all post-construction data in the final HCP.

et al. 2016), although the availability of raptor carcasses was limited and sample sizes were often small. The results from MidAmerican surveys showed that the raptor and vulture carcasses persist on the landscape longer than the typical large bird surrogates. Final results on raptor carcass persistence rates were presented in the second year eagle fatality monitoring report (Bay et al. 2017).

Estimates of carcass persistence rates were used to adjust carcass counts for removal bias. Carcass persistence rates (raptor surrogates) were combined across the fleet. Exponential, log-logistic, lognormal, and Weibull distributions were each fit and the best model was selected using an information theoretic approach known as corrected Akaike Information Criteria (AICc; Burnham and Anderson 2002). The average probability of persistence of a carcass through the search interval, $\hat{r}$, was estimated from an interval censored carcass persistence model.

Estimation of Searcher Efficiency Rates

Searcher efficiency rates were estimated using a logistic regression model. The logistic regression model described the natural logarithm of the odds of finding an available carcass as a function of the above covariate, season. The best model was selected using AICc (Burnham and Anderson 2002). Turkey (*Meleagris gallopavo*) decoys, along with the diurnal raptors provided by the USFWS, were used to estimate searcher efficiency rates.

In total, all 18 facilities were monitored for 10 months over the course of 15 months, but the 15 month periods overlapped by four months only from November 16, 2015, to March 15, 2016. To simplify EoA calculations, the 15-month periods for each facility were considered one period and reported as an "annual" estimate despite the fact that the period included 10 months of the 6-month eagle-year. Thus, for that 15-month period, with a 50% probability, it is estimated that there were seven or fewer fatalities across all 18 studied Projects, given that the probability that a bald eagle carcass was both available to be found and detected was 63.7% across these nine facilities.

The number of exposure events was estimated for each MidAmerican facility by estimating the posterior distribution for exposure rate using data collected during point count surveys at each respective facility. The expansion factor for each facility was estimated from the daylight hours during the fatality monitoring study period, rotor radius, and number of turbines at the facility. The product of the exposure rate and the expansion factor estimates the number of bald eagle exposures within the hazardous area during the fatality monitoring study period (i.e., spring and winter; Table 6a and Table 8). We estimate 7,964.58 exposures during post-construction monitoring from December 2, 2014, to May 15, 2015, and from November 16, 2015, to March 15, 2016, for the first-set of nine facilities, and 956.35 exposures during post-construction monitoring from November 16, 2015,to May 15, 2016, and again from November 16, 2016, to March 15, 2017, for the second-set of nine facilities.

Table 8. Estimated Number of Exposures at Projects Using the Exposure Rate Posterior Distribution for the 18 Facilities that Conducted Post-Construction Monitoring between December 2014 and March 2017.

Project	Expansion Factor for Fatality Monitoring		Exposure Rate		Estimate Number of Exposures from Exposure Rate		Minutes		Survey Hours	
	Spring	Winter	Spring	Winter	Spring	Winter*	Spring	Winter	Spring	Winter
Adair & Morning Light	959.94	1250.70	0.076	0.137	73.14	171.14	5	36	37.60	133
Carroll	414.45	536.01	0.019	0.135	7.88	72.23	0	21	24	79.72
Century	558.17	717.99	0.018	0.006	9.84	3.96	0	0	26	86
Charles City	208.02	266.01	0.023	0.463	4.70	123.25	0	59	20	63
Eclipse	832.52	1,083.44	0.018	0.071	14.67	76.45	0	11	26	83
Highland	2,061553	2633.24	0.007	0.064	15.21	170.62	0	28	64	221
Intrepid	483.99	622.67	0.015	0.019	7.44	11.89	0	3	30	102
Laurel	435.74	564.89	0.185	0.240	80.82	135.62	7	33	20	69
Lundgren	1,027.11	1,324.49	0.013	0.132	13.26	174.96	0	31	36	119
Macksburg	487.37	636.78	0.022	1.905	11.00	1213.47	0	261	20	67
Pomeroy	819.34	1053.57	0.014	0.004	11.84	4.52	0	0	32	111.17
Rolling Hills	1,612.95	2,107.72	0.104	0.761	168.35	1605.42	11	299	55.67	194.50
Vienna I and Vienna II	613.92	793.30	0.019	0.185	11.67	146.56	0	30	24	82
Victory	273.53	353.78	0.023	0.258	6.17	91.23	0	35	20	68
Walnut	421.39	550.10	0.016	0.046	6.92	25.20	0	8	28	96
Wellsburg	576.07	742.37	0.281	0.281	9.46	208.94	0	53	28	94

*Projects were monitored for two seasons

Fatality Predictions

The distribution of predicted annual eagle fatalities (F) is estimated as the product of the expansion factor (ε), the exposure rate (λ), and the collision rate (C):

$$F = \varepsilon \cdot \lambda \cdot C.$$

Credible intervals (i.e., a Bayesian CI) are calculated using a simulation of 100,000 Monte Carlo draws from the distribution of eagle exposure (λ) and the collision rate distribution (C; Manly 1991). The product of each of these draws with the expansion factor was used to estimate the distribution of possible fatalities at the Projects. The upper 80^{th} percentile of this distribution has been recommended by the USWFS as the predicted take for a proposed project (USFWS 2013).

Fatality Predictions Assuming the Eagle Conservation Plan Guidance Collision Rate Prior Distribution

Predicted average and upper 80^{th} credible values for bald eagle fatality rates using the exposure rate posterior distribution (derived from the MidAmerican eagle use data) and the collision rate prior distribution presented in the ECPG are presented in Table 9. The season with the lowest fatality rate is predicted to be the summer, while the season with the highest fatality rate is predicted to be winter.

Table 9. Predicted Average Bald Eagle Fatalities per Season Given the Turbines at MidAmerican Energy Company using the Collision Rate Prior Distribution Presented in the Eagle Conservation Plan Guidance.

Season	Mean	80^{th} Credible Interval
Spring	2.27	3.35
Summer	0.63	0.94
Fall	4.99	7.36
Winter	31.78	46.74
Annual	**39.66**	**58.38**

Fatality Predictions Assuming the Collision Rate Posterior Distribution

Predicted average and upper 80^{th} credible values for bald eagle fatality rates using MidAmerican data on eagle use and fatalities (used to calculate the exposure rate posterior distribution and the collision rate posterior distribution) are presented in Table 10. The season with the lowest fatality rate is predicted to be the summer, while the season with the highest fatality rate is predicted to be the winter.

Table 10. Predicted Average Bald Eagle Fatalities per Season Given the Turbines at MidAmerican Energy Company using the Collision Rate Posterior Distribution.

Season	Mean	80^{th} Credible Interval
Spring	0.31	0.41
Summer	0.09	0.12
Fall	0.68	0.88
Winter	4.31	5.56
Annual	**5.38**	**6.94**

As described above, the predicted annual fatality rate is modeled in the Bayesian framework and assumes a relationship between eagle exposure, collision rate, and eagle fatalities (USFWS 2013).

Bayesian models use existing information to estimate a starting point for the statistical distribution (called the prior probability) for variables of interest and then use new data to update the distribution (called posterior probability distribution). To date, there are far fewer publicly available records of bald eagle fatalities or injuries at wind energy facilities than there are for golden eagles (*Aquila chrysaetos*). Given the limited information previously available for bald eagles, the ECPG Bayesian model relies on data collected on golden eagle use and fatalities from wind energy development in the western U.S. to inform the prior distributions.

Because the life history and behavior of bald eagles are different from those of golden eagles, these species may have differing collision and exposure rates at wind projects. While the prior distributions in the Bayesian model include data collected on golden eagles, MidAmerican has updated the prior distributions with data collected on bald eagles at the Projects. The bald eagle fatality predictions used in this approach are somewhat influenced by the prior distributions developed using data collected on golden eagles; however, given the large amount of data collected at the Projects, their influence is relatively minimal.

<u>Method 2: MidAmerican Energy Company Collision Risk Model</u>

The USFWS Bayesian approach uses statistical models to define the relationship between eagle exposure, collision rate, and fatalities, and accounts for uncertainty (USFWS 2013). New et al. (2015) presented an update to the exposure rate distribution for golden eagles defined in the ECPG and stated that the collision risk model framework can be applied to other avian species. Western EcoSystems Technology, Inc. (WEST) has adapted the collision risk modeling framework presented in the ECPG and New et al. (2015) and has used data collected on bald eagles at the Projects to predict the number of annual fatalities for the MidAmerican Projects. While generally similar to the approach described in Section 2.2.1, Method 2, the MidAmerican Collision Risk Model does not rely on the prior distributions using data on golden eagles exposure and collision rates as the ECPG Bayesian Collision Risk Model does.

The distribution of predicted annual fatalities can be estimated as the product of the expansion factor (ε, hour·km^2), the exposure rate distribution (λ, eagle minutes per hour·km^2), and the collision rate distribution (C, eagle fatalities per exposure):

$$F = \varepsilon \cdot \lambda \cdot C$$

<u>Exposure Rate</u>

The exposure rate (λ) distribution represents the expected number of exposure events (eagle-minutes) per survey hour square kilometer (hour·km^2). An exposure rate (eagle minutes per hour·km^2) was estimated for each Project and was fit to a Gamma distribution. A maximum likelihood estimate was used to estimate the shape and rate parameters (α and β, respectively) of the Gamma distribution for the exposure rate.

The exposure rate distribution for bald eagles was estimated for each season using data collected at point count locations within the Project boundaries. Additional point count data were collected outside of the Projects' boundaries but were not used in this analysis as data were not collected in the spring, summer, and early fall. Seasons were defined as spring (March 16 – May 31), summer (June 1 – July 31), fall (August 1 – October 31), and winter (November 1 – March 15). Data collected from December 1, 2014 to March 31, 2015, and from November 15, 2015 to February 9, 2016, were combined to estimate the exposure rate for winter. The average bald eagle exposure rate at the Projects was highest in the winter (0.295 flight minutes observed per hour of survey per km^2) and lowest in the summer (0.014 flight minutes observed per hour of survey per km^2; Table 11 and Table 12).

The probability distribution for the exposure rate is: $\lambda \sim$ Gamma (α, β). Parameters for the distribution, mean, and standard deviation for each season are presented in Table 12.

Table 11. Bald Eagle Minutes, Survey Effort, and Exposure Rate by Season for Projects where Avian Point Count Surveys were Conducted[a].

Facility	Spring			Summer			Fall			Winter		
	Eagle Minutes	Survey Effort	Exposure Rate	Eagle Minutes	Survey Effort	Exposure Rate	Eagle Minutes	Survey Effort	Exposure Rate	Eagle Minutes	Survey Effort	Exposure Rate
Adair & Morning Light	5	37.6	0.066	0	56.1	0.009	0	54.0	0.009	36	133.0	0.135
Carroll	0	24.0	0.021	0	36.0	0.014	0	30.6	0.016	21	79.7	0.131
Century	0	26.0	0.019	0	39.0	0.013	2	36.0	0.028	0	86.0	0.006
Charles City	0	20.0	0.025	0	30.0	0.017	0	24.0	0.021	59	63.0	0.466
Eclipse	0	26.0	0.019	0	51.6	0.010	0	25.0	0.020	11	83.0	0.066
Highland	0	64.0	0.008	0	96.0	0.005	3	96.0	0.016	28	221.0	0.063
Intrepid	0	30.0	0.017	0	45.0	0.011	0	45.0	0.011	3	102.0	0.015
Laurel	7	20.0	0.174	0	30.0	0.017	3	27.0	0.055	33	69.0	0.238
Lundgren	0	36.0	0.014	0	54.0	0.009	0	54.0	0.009	31	119.0	0.130
Macksburg	0	20.0	0.025	0	40.0	0.012	19	20.0	0.472	261	67.0	1.937
Pomeroy	0	32.0	0.016	0	48.0	0.010	8	48.0	0.083	0	111.2	0.004
Rolling Hills	11	55.7	0.098	9	84.0	0.053	30	82.0	0.182	299	194.5	0.765
Victory	0	20.0	0.025	0	30.0	0.017	0	27.6	0.018	35	68.0	0.256
Vienna	0	24.0	0.021	1	35.4	0.014	0	36.0	0.014	30	82.0	0.182
Walnut	0	28.0	0.018	0	55.7	0.009	0	28.0	0.018	8	96.0	0.041
Wellsburg	0	28.0	0.018	1	42.0	0.012	0	42.0	0.012	53	94.0	0.280

[a] For facilities that observed no eagle minutes, a conservative assumption was made that a single eagle minute was observed for model exposure rates in the Gamma distribution.

Table 12. Estimated Parameters and Statistics for the Exposure Rate Distribution (λ) by Season from Bald Eagle Observations Made during Point Count Surveys at the Projects.

Variable	Spring	Summer	Fall	Winter
α	1.48	3.67	0.71	0.61
β	40.77	254.02	11.60	2.07
Mean	0.036	0.014	0.061	0.295
Standard Deviation	0.030	0.008	0.073	0.377

Expansion Factor

The expansion factor (ε) is used to scale the per unit fatality rate (fatalities per hour per km^2) to the daylight hours (τ) and total hazardous area (km^2) within the Project area. The expansion factor is:

$$\varepsilon = \tau \sum_{i=1}^{n} \delta_i,$$

where n is the number of turbines, and δ is the circular area (two-dimensional hazardous area) centered at the base of a turbine having radius equal to the rotor-swept radius of the turbine (or proposed turbine).

The sunrise and sunset times from each facility were used to calculate the daylight hours at Projects (U.S. Naval Observatory 2016). The expansion factor for each facility was calculated based on the daylight hours, number of turbines at the facility, and the rotor radius. The overall expansion factor for the MidAmerican Fleet was calculated as the sum of the expansion factors from the facilities. The expansion factors for the MidAmerican Fleet are 16,194; 14,207; 17, 790; and 20,293 for spring, summer, fall, and winter, respectively. The expansion factors for each facility in the MidAmerican Fleet are given in Table 6b.

Collision Rate

The collision rate distribution, *C*, represents the rate at which an eagle would collide with a turbine per exposure in the hazardous area, where all collisions are considered to be fatal. The number of bald eagle collisions that occurred during post-construction monitoring surveys (*f*: fatalities estimated during post-construction monitoring surveys) was estimated and accounts for carcasses being removed by scavengers, imperfect searcher detection rates, and/or bald eagles that may have fallen outside of the plots searched.

The number of exposures expected to occur during post-construction monitoring surveys was estimated by calculating the expansion factor during post-construction monitoring surveys and applying the exposure rate (g: $\varepsilon_{\text{post-construction monitoring}} \cdot \lambda$). The average collision rate was estimated as f/g, and the standard deviation was estimated using bootstrapping (Manly 1991). A method of moments approach was used to estimate the shape and rate parameters (ν and ν', respectively) for the collision rate distribution, assuming the data follow a Beta distribution.

To obtain the collision rate distribution, the number of bald eagle fatalities and the number of exposure events that did not result in a fatality were estimated. During post-construction monitoring between late 2014 and March 2017, five bald eagle fatalities were reported during standardized carcass searches, two of which were either outside the survey period or search plot. Thus, three bald eagle fatalities were included in fatality rate estimation. However, the overall probability that a bald eagle carcass was both available to be found and detected at a facility during monitoring was less than 100% given carcasses removed by scavengers, imperfect searcher detection rates, and/or bald eagles that may have fallen outside of the plots searched. Taking into account these reductions in probability detection, MidAmerican estimates that seven bald eagle fatalities occurred during the post-construction monitoring study period under the EoA framework (Table 13).

The number of exposure events was estimated for each facility by estimating the exposure rate from point count surveys data collected at each respective facility. The expansion factor for each facility was estimated from the survey length of fatality monitoring, rotor radius, and number of turbines at the facility. The product of the exposure rate and the expansion factor during fatality monitoring estimates the number of bald eagle exposures within the hazardous area during fatality monitoring (Tables 6a and 13). WEST estimates 8.908.5 exposures during post-construction monitoring.

The probability distribution for the collision rate was: $C \sim \text{Beta}(v, v')$, with parameters v =2.13 and v' = 2.705.84. The mean and standard deviation of the estimated collision rate were 0.00079 and 0.00054, respectively.

Table 13. Estimated Number of Exposures at Projects using the Exposure Rate Distribution for the 18 Facilities That Conducted Post-Construction Monitoring between December 2014 and March 2017.

Project	Expansion Factor for Fatality Monitoring		Exposure Rate		Estimate Number of Exposures from Exposure Rate		Estimate Number of Exposures from Exposure Rate	Estimated Number of Bald Eagle Fatalities
	Spring	Winter	Spring	Winter	Spring	Winter*		
Adair & Morning Light	959.94	1250.70	0.066	0.135	63.49	168.37	400.24	0
Carroll	414.45	536.01	0.021	0.131	8.59	70.23	149.05	2
Century	558.17	717.99	0.019	0.006	10.68	4.15	18.98	0
Charles City	208.02	266.01	0.025	0.466	5.17	123.9	252.97	0
Eclipse	832.52	1083.44	0.019	0.066	15.93	71.42	158.76	0
Highland	2060.52	2633.24	0.008	0.063	16.01	165.94	347.89	2
Intrepid	483.99	622.67	0.017	0.015	8.02	9.11	26.24	0
Laurel	435.76	564.89	0.174	0.238	75.86	134.37	344.60	0
Lundgren	1027.11	1324.49	0.014	0.130	14.19	171.61	357.40	0
Macksburg	487.37	636.78	0.025	1.937	12.12	1233.75	2479.61	3
Pomeroy	819.34	1053.57	0.016	0.004	12.73	4.71	22.15	0
Rolling Hills	1612.95	2107.72	0.098	0.765	158.52	1611.52	3381.56	0
Victory	273.53	353.78	0.025	0.256	6.80	90.57	187.93	0
Vienna	613.90	793.30	0.021	0.182	12.72	144.35	301.42	0
Walnut	421.39	550.10	0.018	0.041	7.49	22.8	53.08	0
Wellsburg	576.07	742.37	0.018	0.280	10.23	208.18	426.59	0

*Projects were monitored for two seasons.

Fatality Predictions

Fatality predictions for the MidAmerican Fleet were estimated using the collision rate and exposure rate distributions developed using data collected on bald eagles. Confidence intervals were calculated using a simulation of 100,000 Monte Carlo draws from the distributions of eagle exposure and the collision rate distribution (Manly 1991). The product of each of these draws, with the expansion factor was used to estimate the distribution of possible fatality at the Projects. The upper 80th percentile of this distribution has been recommended by the USWFS as a conservative estimate of take for a proposed project (USFWS 2013).

Predicted average and upper 80th percentile for bald eagle fatality rates using the exposure and collision rate distributions developed for MidAmerican are presented in Table 14. The season with the lowest fatality rate is expected to be summer, while the season with the highest fatality rate is expected to be winter.

Table 14. Estimated Average Bald Eagle Fatalities per Season given the 2,020 Turbines at MidAmerican Energy Company using the Collision Rate Posterior Distribution.

Season	Mean	80th Percentile
Spring	0.46	0.71
Summer	0.16	0.24
Fall	0.86	1.28
Winter	4.72	6.97
Annual	**6.20**	**9.00**

Method 3: Evidence of Absence and MidAmerican Energy Company Fatality Monitoring Data

Take at the Projects was estimated from post-construction monitoring data using the EoA method. Bald eagle fatalities are a rare event at wind facilities and it is unlikely that a large number of bald eagle fatalities would be found during standardized searches. EoA was used as Horvitz-Thompson estimators are highly biased when the number of carcasses found is less than 10 (Korner-Nievergelt et al. 2011).

Evidence of Absence

The EoA method utilizes a statistical hierarchical model to estimate the actual number of fatalities from the number found and probability of discovery. The EoA estimator assumes the number of carcasses found during searches at a particular facility follows a binomial distribution, i.e.:

$$X \sim binomial(M, g)$$

where X is the total number of carcasses from all searches, M is the (unknown) number of eagle carcasses, and g is probability of discovering a carcass. Discovery probability g is the product of the probability that a turbine kills an individual eagle, the probability that the carcass persists for the next two searches, and the probability that technicians detect the carcass during those searches. Discovery probability is estimated from the frequency of visits, searcher efficiency information, carcass persistence, and the proportion of the entire area being searched. Similar to the EoA methods for bats, the eagle EoA method assumed the total number of eagle fatalities (M) followed an objective prior, i.e.

$$M \sim Objective \ = \sqrt{M+1} - \sqrt{M}.$$

The study periods implemented during monitoring and the seasonal presence of eagles impacted computation of probability of discovery, g. Computation of eagle g is explained next.

Study Periods

Eagles were assumed to present at the Projects only during the 6-month period of time between November 16 and May 15 each year. The season between May 15 and November 15 was ignored in these calculations (zero mortality assumed). Thus, the winter and spring periods were deemed "eagle-years". Annual estimates of take apply to eagle-years.

All 18 facilities were monitored for 10 months over the course of 15 months, but the 15-month periods overlapped by four months, from November 16, 2015, to March 15, 216. To simplify EoA calculations, the 15-month periods for each facility were considered one period and reported as an “annual” estimate despite the fact that the period included 10 months of the 6-month eagle-year. Reporting estimates in this way results in a slight over-estimate of annual eagle take.

Monitoring began at one additional facility (Adams) on May 16, 2016, and continued through May 15, 2017. This facility was excluded from the calculations because the monitoring period was much shorter and thus the results are incompatible to the other Projects. The Adams facility was considered an "unbuilt" facility, along with Ida Grove, O’Brien, and the State Fair turbine.

g Estimates

Eagle g values were computed using the single-site single-year module of the EoA R statistical package. These computations used facility-specific search schedules, searcher efficiency for raptor surrogates, and searched area corrections. Carcass persistence trials were pooled across facilities due to the low number of trials available at any one facility. The arrival distribution of eagle carcasses was modeled as uniform (constant) during the eagle-year. Carcass searches occurred approximately monthly during Winter1 and Spring1 (mean of 27.4 days), and approximately every two weeks during Winter2, Spring2, and Winter3 (mean of 15.3 days).

Due to the 15-month study period and seasonality in eagle presence, the EoA probability of discovery parameter, g, was computed twice for each facility. Once during its first six months of monitoring (a winter and a spring combined), and again during its final four months of monitoring (a winter). A weighted average of the two facility-specific g values, with weights equal to 6 (months) and 4 (months), was computed and resulted in a single g for each facility. The Fleet-wide g value was computed by weighted average of the project-specific g’s. Weights used to compute the Fleet-wide g were the number of turbines at each facility. The Fleet-wide g was assumed to follow a beta distribution,

$$g \sim beta(\alpha, \beta)$$

where α and β were computed by method of moments from Project specific g's after weighting by number of turbines.

Given prior distributions for M and g, a posterior distribution for the parameter of interest (M) was estimated using Bayesian methods. For expediency and transparency, the posterior distribution of M was estimated by MCMC sampling in JAGS software (Plummer 2003). The point estimate reported here was the median of the posterior for M, while posterior credible intervals for M were computed as the lower and upper 5% quantiles from the posterior, which form a 90% credible interval.

Facilities under Construction

Prior to estimation via EoA, the observed number of carcasses was potentially expanded to account for additional turbines in un-built and un-monitored facilities covered by the Permit. Found carcasses were expanded by computing the mean number of carcasses per monitored turbine over all facilities and time periods, and multiplying this mean rate by the number of un-built turbines. This procedure assumes the per-turbine fatality rate at facilities under construction equals the per-turbine fatality rate at monitored facilities. In addition, this procedure assumes searcher efficiency, carcass removal, area correction, and search interval at facilities under construction were equal to the Fleet-wide analogous quantity on monitored facilities. That is, the Fleet-wide g was used for facilities under construction. The expanded number of carcasses was rounded to the nearest integer and used in the EoA method.

Results

Based on the 15-month monitoring results for all 18 facilities, but accounting for the unsearched facilities, the estimated take was six bald eagle fatalities (90% CI [4, 10]). The site-wide probability a carcass was available and detected was 67.3% (95% CI: 66.0%, 68.6%).

Summary of Eagle Take Estimates

In summary, three different approaches of predicting and estimating bald eagle take at MidAmerican facilities were used, including:

- Method 1: ECPG Bayesian Collision Risk Model
- Method 2: MidAmerican Collision Risk Model
- Method 3: Evidence of Absence

Table 15 summarizes the take predictions and estimates calculated by the three methods.

Table 15. Bald Eagle Take Predictions/Estimates at MidAmerican Energy Company's Wind Energy Projects in Iowa.

Method 1	Method 2	Method 3
6.94 eagles/year	9.00 eagles/year	6 eagles/year

Populations of bald eagles have been growing in the Midwest over recent years (USFWS 2016). However, recent midwinter eagle counts done by the Iowa Department of Natural Resources suggest bald eagle populations during the winter may be leveling off in Iowa (see HCP Section 3.5.3.2). MidAmerican proposes to use Method 2 for purposes of estimating eagle take for the Incidental Take Permit (ITP or Permit). By using the 80th credible interval for Method 2, a conservative approach has been used that would not likely be exceeded even if the eagle population continues to grow over the Permit term.

Estimated Bald Eagle Take with Minimization Measures

The analyses presented in above represent bald eagle mortality that can be expected under normal operating conditions. A discussion of minimization measures that are expected to reduce the risk to bald eagles (corresponding to Stage 4 of the ECPG) is presented in this section.

In addition to fall curtailment, MidAmerican presently implements a landowner engagement strategy at its wind facilities within the action area to minimize disposal of animal carcasses in areas that could serve as a source of attraction for eagles and other raptors. MidAmerican issues a regular newsletter ("*Wind Advantage*") to participating landowners containing information about company activities and best management practices. MidAmerican will continue to include information in this newsletter regarding carcass disposal and wildlife attraction and interaction. MidAmerican will also develop and distribute outreach materials, including letters and informational brochures or website content informing participating, neighboring, and non-participating landowners of possible wildlife interactions resulting from carcass disposal practices. Finally, MidAmerican will continue to work to establish collaborative outreach efforts with Iowa agricultural industry stakeholders, such as Iowa Pork Producers Association, Iowa Farm Bureau Federation, Iowa State University Extension and Outreach, and others, as appropriate. This measure is anticipated to reduce annual bald eagle mortality at the Project, but no quantitative estimates of reduced eagle fatalities exist from proper disposal of animal carcasses at this time.

Additionally, MidAmerican currently implements a carrion removal strategy that consists of an incidental wildlife carcass discovery and reporting protocol for the wind technicians at wind facilities within the action area. This protocol includes an access road and turbine pad scan each time a technician visits a turbine. All turbines are visited at least monthly. In addition, MidAmerican will develop a training program to educate wind operations and maintenance staff and wind technician staff about incidental wildlife roadkill discoveries, reporting, and disposal. Carcass observations by operations and maintenance and wind technician staff will be based on incidental discoveries through the normal course of duties and not resulting from a systematic search. Based on risk at a given Project, MidAmerican may investigate other protocols, including systematic searches of public roads within the Project area or agreements with a third party, such as local secondary road departments or the Department of Transportation. This measure is anticipated to reduce annual bald eagle mortality at the Project, but no quantitative estimates of reduced eagle fatalities exist from carrion removal at this time.

Given the uncertainty with regard to reductions in bald eagle mortality resulting from these minimization measures, MidAmerican is applying for an ITP authorizing take based on the estimated take without minimization measures.

LITERATURE CITED

Bay, K., E. B. J. Studyvin, M. Kauffman, and S. Hamilton. 2016. 2014-2015 Post-Construction Fatality Monitoring: Bat-Focused Surveys. MidAmerican Energy Company Iowa Wind Energy Portfolio: Carroll, Victory, Lundgren, Walnut, Rolling Hills, Adair, Eclipse, Morning Light, and Macksburg. December 2014 – November 2015. Prepared for MidAmerican Energy Company, Urbandale, Iowa. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming.

Bay, K., E. Baumgartner, J. Studyvin, and R. McDonald. 2017. 2015-2016 Post-Construction Fatality Monitoring: Bat-Focused Surveys MidAmerican Iowa Wind Energy Portfolio: Adams, Century, Charles City, Highland, Intrepid, Laurel, Lundgren, Macksburg, Pomeroy, Rolling Hills, Vienna I, Vienna II, and Wellsburg. November 2015 - November 2016. Prepared for MidAmerican Energy Company, Urbandale, Iowa. Prepared by Western EcoSystems Technology, Inc. Cheyenne, Wyoming.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. 2nd Edition. Springer, New York, New York.

Chodachek, K., C. Derby, M. Sonnenberg, and T. Thorn. 2012. Post-Construction Fatality Surveys for the Pioneer Prairie Wind Farm I LLC Phase II, Mitchell County, Iowa: April 4, 2011 – March 31, 2012. Prepared for EDP Renewables, North America LLC, Houston, Texas. Prepared by Western EcoSystems Technology, Inc., Bismarck, North Dakota. August 27, 2012.

Chodachek, K., C. Derby, K. Adachi, and T. Thorn. 2014. Post-Construction Fatality Surveys for the Pioneer Prairie II Wind Energy Facility, Mitchell County, Iowa. Final Report: July 1 - October 18, 2013. Prepared for EDP Renewables, North America LLC, Houston, Texas. Prepared by Western EcoSystems Technology Inc. (WEST), Bismarck, North Dakota. April 2014.

Dalthorp, D., M. Huso, D. Dail, and J. Kenyon. 2014. Evidence of Absence Software User Guide. US Geological Survey (USGS) Data Series 881. USGS, Reston Virginia. September 19, 2014. Available online: http://pubs.usgs.gov/ds/ 0881/pdf/ds881.pdf

Derby, C., K. Chodachek, and K. Bay. 2010a. Post-Construction Bat and Bird Fatality Study Crystal Lake II Wind Energy Center, Hancock and Winnebago Counties, Iowa. Final Report: April 2009 – October 2009. Prepared for NextEra Energy Resources, Juno Beach, Florida. Prepared by Western EcoSystems Technology, Inc. (WEST), Bismarck, North Dakota. June 2, 2010.

Derby, C., K. Chodachek, K. Bay, and A. Merrill. 2010b. Post-Construction Fatality Surveys for the Winnebago Wind Project: March 2009- February 2010. Prepared for Iberdrola Renewables, Inc. (IRI), Portland, Oregon. Prepared by Western EcoSystems Technology, Inc. (WEST), Bismarck, North Dakota.

Derby, C., K. Chodachek, K. Bay, and S. Nomani. 2011. Post-Construction Fatality Surveys for the Barton I and II Wind Project: IRI. March 2010 – February 2011. Prepared for Iberdrola Renewables, Inc. (IRI), Portland, Oregon. Prepared by Western EcoSystems Technology, Inc. (WEST), Bismarck, North Dakota. Version: September 28, 2011.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 1995. Bayesian Data Analysis. Chapman and Hall, London, U.K.

Huso, M. 2011. An Estimator of Wildlife Fatality from Observed Carcasses. Environmetrics 22(3): 318-329. doi: 10.1002/env.1052.

Huso, M., N. Som, and L. Ladd. 2012. Fatality Estimator User's Guide. U.S. Geological Survey (USGS) Data Series 729. December 11, 2012. 22 pp. Available online at: http://pubs.usgs.gov/ds/729/pdf/ds729.pdf

Jain, A. 2005. Bird and Bat Behavior and Mortality at a Northern Iowa Windfarm. Thesis. Iowa State University, Ames, Iowa.

Korner-Nievergelt, F., P. Korner-Nievergelt, O. Behr, I. Niermann, R. Brinkmann, and B. Hellriegel. 2011. A New Method to Determine Bird and Bat Fatality at Wind Energy Turbines from Carcass Searches. Wildlife Biology 17: 350-363.

New, L., E. Bjerre, B. Millsap, M. C. Otto, and M. C. Runge. 2015. A Collision Risk Model to Predict Avian Fatalities at Wind Facilities: An Example Using Golden Eagles, *Aquila chrysaetos*. PLoS ONE: doi: 10.1371/journal.pone.0130978.

Manly, B. F. J. 1991. Randomization and Monte Carlo Methods in Biology. Chapman and Hall, London, United Kingdom.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. Available online at: http://mcmc-jags.sourceforge.net/

Simon, S., T. Mattson, and E. Baumgartner. 2016. 2014 – 2016 Eagle Use Surveys, MidAmerican Energy Company Iowa Wind Energy Portfolio 2014 – 2016. Prepared for MidAmerican Energy Company, Urbandale, Iowa. Prepared by Western EcoSystems Technology, Inc. (WEST).

Urquhart, B., S. Hulka, and K. Duffy. 2015. Game Birds Do Not Surrogate for Raptors in Trials to Calibrate Observed Raptor Collision Fatalities. Bird Study 62(4): 552-555. doi: 10.1080/00063657.2015.105375.

U.S. Fish and Wildlife Service (USFWS). 2012. Eagle Conservation Plan Guidance. Module 1 - Land-Based Wind Energy Technical Appendices. Division of Migratory Bird Management, USFWS. August 2012.

U.S. Fish and Wildlife Service (USFWS). 2013. Eagle Conservation Plan Guidance: Module 1 - Land-Based Wind Energy, Version 2. US Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management. April 2013. Executive Summary and frontmatter + 103 pp. Available online: https://www.fws.gov/migratorybirds/pdf/management/eagleconservationplanguidance.pdf

U.S. Fish and Wildlife Service (USFWS). 2016. Midwest Wind Energy Multi-Species Habitat Conservation Plan, Public Review Draft. April 2016. Available online: http://www.midwestwindhcp.com/documents.htm

U.S. Naval Observatory. 2016. Rise and Set for the Sun. Astronomical Applications Department, U.S. Naval Observatory, Washington, D.C. Data accessed 2016. http://aa.usno.navy.mil/data/docs/RS_OneYear.php

Whitfield, D. P. 2009. Collision Avoidance of Golden Eagles at Wind Farms under the 'Band' Collision Risk Model. Report to Scottish National Heritage. March 2009.

ADDENDUM 1 - SPECIES COMPOSITION OF COVERED BAT FATALITIES

Objective

Provide estimates and 90% CIs for the SC method of estimating the number of INBA, LBBA, NLEB, and TRBAs taken by the Projects.

Methods

The usual method for estimating a binomial proportion relies on maximum likelihood: (# successes)/(# trials). However, it has long been recognized (e.g., Wilson 1927) that this point estimate and the associated CI perform poorly when there are few "successes", i.e., when the true proportion is very small. An alternative approach recommended by Agresti and Coull (1998), and discussed further by Brown et al. (2001), has been used in previous reports by various authors to compute the proportion of each rare species and its associated variance. While the CI estimates of Agresti and Coull (1998) provide excellent coverage for proportions, the point estimate (center of the CI) is biased high, especially for small proportions. Here, we opted for a Bayesian estimator of the SC ratio, which is less biased and does not produce zero estimates. The Bayesian estimator of a proportion we used in the SC method is described in the methods section pertaining to bats in the main text of this Appendix.

In this addendum, we describe in detail methods to arrive at a Fleet-wide estimate of Covered Bat species carcasses. In particular, we describe estimation of the SC ratio and variance estimates for the Fleet-wide Covered Bat mortality. These variance estimates rely on a combination of bootstrapping, the posterior distribution of *p*, and the formula for variance of a product derived by the delta method.

Let x be the number of carcasses of a particular Covered Bat species found at MidAmerican facilities during 2015 and 2016 monitoring efforts. To improve accuracy of a Covered Bat species carcass ratio, we expanded the data set when $x = 0$ until one or more fatalities of the species had been observed. Hence, x was set to either the number of Covered Bat species carcasses found at all MidAmerican Projects or at all MidAmerican projects plus all other publically-available monitoring data sets from wind facilities in Iowa. Let n be the total count of all bat carcasses in the same data set (i.e., either MidAmerican or MidAmerican+Iowa public data).

The Bayesian method we employed assumed an uninformative Jeffery's prior distribution for p, the *beta*(0.5, 0.5) distribution. With this assumption, the mean of the posterior distribution for p is:

$$\hat{p} = \frac{x + 0.5}{n + 1}$$

which we use as the point estimator. The estimated variance of $\hat{p}$ is:

$$\hat{\sigma}_{\hat{p}}^2 = \frac{(x+0.5)(n-x+0.5)}{(n+1)^2(n+2)}.$$

Let $\hat{f}_{all}$ be the estimated number of fatalities per turbine derived from data on carcass count, searcher efficiency, carcass persistence, and proportion of area searched (Huso, 2011, Huso et al. 2012). All-bat fatalities ($\hat{f}_{all}$) was computed separately for each facility as well as the fleet. Facility specific estimates of $\hat{f}_{all}$ for the three facilities sampling in both 2015 and 2016 were averaged to arrive at a single $\hat{f}_{all}$ for these facilities. Fleet-wide all-bat estimates were computed using the turbine-weighted averaged of $\hat{f}_{all}$ over facilities.

Let $\hat{\sigma}^2_{f_{all}}$ be the estimated variance of $\hat{f}_{all}$ derived by bootstrap resampling all raw monitoring data. Bootstrap estimates of $\hat{\sigma}^2_{f_{all}}$ were obtained by resampling carcasses, searcher efficiency and carcass persistence trials, and area correction data 1,000 times with replacement. From each bootstrap sample a new estimate of all bat fatality was computed, ultimately yielding 1,000 random estimates of $\hat{f}_{all}$. The variance of these 1,000 values was used as $\hat{\sigma}^2_{f_{all}}$.

The fleet-wide estimate of all bat mortalities was derived as the average all-bat mortality per turbine multiplied by the number of turbines in the fleet:

$$\hat{F}_{all} = T\ \hat{f}_{all}$$

where T is total number of turbines in the fleet. The total number of turbines in the fleet was T = 2,020, except for INBAs which had a smaller range. The number of turbines in INBA territory was 567 turbines. The variance of fleet-wide all-bat mortality was derived by treating the number of turbines as a constant, i.e.:

$$\hat{\sigma}^2_{F_{all}} = T^2\ \hat{\sigma}^2_{f_{all}}.$$

The Species Composition estimate of fatalities for the rare species associated with $\hat{p}$ was

$$\hat{F}_{rare} = \hat{p}\,\hat{F}_{all}$$

and its estimate variance was:

$$\hat{\sigma}^2_{F_{rare}} = \hat{\sigma}^2_p\ \hat{\sigma}^2_{F_{all}} + \hat{p}^2\ \hat{\sigma}^2_{F_{all}} + \hat{\sigma}^2_p\ \hat{F}^2_{all} \quad .$$

This is the formula for the variance of the product of two random variables, assuming independence. For comparison purposes, CIs for the estimate of rare species fatalities was derived assuming approximate normality of $\hat{F}_{rare}$, i.e.

$$\hat{F}_{rare} \mp z\sqrt{\sigma^2_{F_{rare}}}.$$

The lower endpoint of this interval was truncated to zero if it was negative. Only $\hat{\sigma}^2_{F_{rare}}$ and $\hat{F}_{rare}$ were used in the IEoA method outlined in the main text, not CI endpoints.

Results

No NLEB carcasses were found at Project facilities during 2015 and 2016; hence, publicly available data from other Iowa wind facilities were used in addition to information from the Project facilities (Table 1, this Addendum) to compute the species composition for this species. MidAmerican-specific monitoring data was used to compute the species composition ratio for LBBAs and TRBAs. INBAs occur only at a subset of MidAmerican facilities. Consequently, the species composition ratio for INBA was computed from data collected at the following eight facilities in the INBA range: Adair, Eclipse, Laurel, Macksburg, Morning Light, Rolling Hills, Vienna I, and Vienna II.

Table 1. Bat Carcass Counts for MidAmerican Projects in 2015 and 2016 ("Data" = MidAmerican), and in Publicly Available Data Sets for Other Facilities in Iowa ("Data" = Public).

Project	# INBA	# LBBA	# NLEB	# TRBA	Total Bats	Data	# Turbines
Adair (2015)	0	0	0	0	54	MidAmerican	76
Adams (2016)	0	0	0	4	193	MidAmerican	64
Carroll (2015)	0	0	0	0	56	MidAmerican	100
Century (2016)	0	1	0	2	188	MidAmerican	145
Charles City (2016)	0	13	0	0	101	MidAmerican	50
Eclipse (2015)	0	0	0	1	72	MidAmerican	87
Highland (2016)	0	1	0	7	375	MidAmerican	214
Intrepid (2016)	0	0	0	0	188	MidAmerican	122
Laurel (2016)	0	1	0	0	96	MidAmerican	52
Lundgren (2015)	0	26	0	7	297	MidAmerican	107
Lundgren (2016)	0	4	0	2	247	MidAmerican	107
Macksburg (2015)	0	8	0	7	151	MidAmerican	51
Macksburg (2016)	1	6	0	3	190	MidAmerican	51
Morning Light (2015)	0	0	0	1	49	MidAmerican	44
Pomeroy (2016)	0	0	0	1	125	MidAmerican	184
Rolling Hills (2015)	0	0	0	2	128	MidAmerican	193
Rolling Hills (2016)	0	1	0	5	253	MidAmerican	193
Victory (2015)	0	0	0	0	21	MidAmerican	66
Vienna I (2016)	0	3	0	1	123	MidAmerican	45
Vienna II (2016)	0	2	0	1	53	MidAmerican	19
Walnut (2015)	0	0	0	0	79	MidAmerican	102
Wellsburg (2016)	0	7	0	1	169	MidAmerican	60
Barton I & II	0	0	0	0	20	Public	
Crystal Lake II	0	0	0	0	148	Public	
Pioneer Prairie (2011-2012)	0	0	0	0	74	Public	
Pioneer Prairie (2013)	0	0	2	0	83	Public	
Pioneer Prairie (2014)	0	0	0	0	0	Public	
Top of Iowa (2003)	0	0	0	0	32	Public	
Top of Iowa (2004)	0	0	0	0	46	Public	
Winnebago	0	0	0	0	10	Public	

Facility-specific all-bat fatality estimates ranged from 8.49 to 142.21 bats per turbine per year (Table 2, this Addendum). Fleet-wide turbine-weighted average fatalities for LBBAs, TRBAs, and NLBAs was 22.45 bats per turbine per year, while the Fleet-wide estimate of INBA fatalities was

27.41 bats per turbine per year (Table 3, this Addendum). The smallest estimated species proportion in found carcasses was NLBAz (0.00069), followed by INBAz (0.0013), TRBAz (0.014) and LBBAz (0.023) (Table 3, this Addendum). Fleet-wide species composition estimates of Covered Bat fatalities was lowest for INBAz (19.95/year), followed by NLBAz (31.29/year), TRBAz (642.95/year), and LBBAz (1038.62/year) (Table 2, main Appendix; Table 4, this Addendum).

Table 2. Facility-Specific Estimates of All-Bat Fatalities (Bats per Year) at MidAmerican Projects in 2015 and 2016.

Facility	2015	2016
Adair	28.03	-
Adams	-	24.34
Carroll	15.06	-
Century	-	13.61
Charles City	-	15.62
Eclipse	19.92	-
Highland	-	20.24
Intrepid	-	27.55
Laurel	-	32.71
Lundgren	55.12	20.64
Macksburg	142.21	25.31
Morning Light	39.65	-
Pomeroy	-	9.38
Rollinghills	11.87	14.48
Victory	8.49	-
Vienna I	-	21.32
Vienna II	-	24.11
Walnut	28.03	-
Wellsburg	-	28.87

Table 3. Bayesian Species Composition Ratios ($\hat{p}$), Fleet-Wide All-Bat Mortality Estimates ($\hat{F}_{all}$; Bats/Turbine/Year), and Associated Estimated Variances.

Species	x	n	$\hat{p}$	$\hat{\sigma}^2_{\hat{p}}$	$\hat{F}_{all}$	$\hat{\sigma}_{\hat{F}_{all}}$
INBA	1	1169	0.00128	1.09e-06	27.41	10.07
LBBA	73	3208	0.02290	6.97e-06	22.45	3.00
NLEB	2	3621	0.00069	1.90e-07	22.45	3.00
TRBA	45	3208	0.01418	4.35e-06	22.45	3.00

Table 4. Species Composition Estimates of Covered Bat Fatalities ($\hat{F}_{rare}$) and (Truncated at 0) 90% Confidence Intervals.

	Bats/Turbine/Year		Bats /Year	
Species	F_{rare}	**90% CI**	F_{rare}	**90% CI**
INBA	0.06	(0.00, 0.12)	19.95	(0.00, 47.18)
LBBA	0.52	(0.4, 0.64)	1038.62	(801.11, 1276.12)
NLEB	0.02	(0.00, 0.04)	31.30	(0, 64.18)
TRBA	0.32	(0.24, 0.41)	642.95	(466.79, 819.12)

LITERATURE CITED

Agresti, A. and B. A. Coull. 1998. Approximate is Better than "Exact" for Interval Estimation of Binomial Proportions. American Statistician 52: 119-126.

Brown, L. D., T. T. Cai, and A. DasGupta. 2001. Interval Estimation for a Binomial Proportion. Statistical Science 16:101-133.

Huso, M. 2011. An Estimator of Wildlife Fatality from Observed Carcasses. Environmetrics 22(3): 318-329. doi: 10.1002/env.1052.

Huso, M., N. Som, and L. Ladd. 2012. Fatality Estimator User's Guide. U.S. Geological Survey (USGS) Data Series 729. December 11, 2012. 22 pp. Available online at: http://pubs.usgs.gov/ds/729/pdf/ds729.pdf

Wilson, E. B. 1927. Probable Inference, the Law of Succession, and Statistical Inference. Journal of the American Statistical Association 22: 209-212.

ADDENDUM 2 - EVIDENCE OF ABSENCE METHODS

Introduction

The term "Evidence of Absence" is used to refer to a number of different things. It can refer to a Bayesian fatality estimator (Huso et al. 2015). It can refer to an adaptive management framework that assumes use of the EoA estimator to track compliance with HCPs (Dalthorp and Huso 2015). It can refer to a software library for the R statistical computing platform that implements some variants of the EoA estimator (Dalthorp et al 2014)[4]. It can refer to the Design Tradeoffs module within the EoA software, which is used to determine the outcome of different monitoring design parameters on the probability to detect carcasses during searches. Or it can refer to the Scenario Explorer module within the EoA software, which uses simulation to investigate the likely outcomes of adaptive management regimes during the course of ITP permits. In this document, reference to EoA refers broadly to the Bayesian fatality estimator. Reference to the software, the adaptive management framework, or other modules within the software will be explicitly noted as such.

Evidence of Absence Overview[5]

Model Form

The EoA estimator takes as inputs the number of carcasses *X* found during searches along with an estimate of the accompanying probability to detect those carcasses *g*. From these it estimates the minimum number of carcasses *m* that arrived during the study:

$$Pr(M \geq m \mid X, g) \leq \alpha \quad (1)$$

where

M is the total number of carcasses, (Poisson-distributed);
m is the point estimate at the credibility level $1 - \alpha$;
X is the count of carcasses from searches, (binomially-distributed);
g is the probability to detect a carcass, given that occurred (beta-distributed); and
$1 - \alpha$ is the desired credibility for the estimate.

In the use of this model, α is specified in a way appropriate to the situation (i.e. it is driven by policy), *X* is known exactly from data, *g* is unknown and estimated as $\hat{g}$, and a prior distribution is specified for *M*. The estimate of fatality *m* is obtained by calculating the posterior distribution for *M* and extracting the 100(1-α)% upper credible bound (or quantile) from the posterior distribution. When the desired estimate is a fatality rate rather than a total number of fatalities, we estimated

[4] The citation is the user manual for version 1.0. The EoA software is currently in version 1.06 with version 2.0 in beta testing, but the most recent documentation is for version 1.0.

[5] The EoA framework is rich with notation. Table 1 at the end of this addendum lists all notation used in the addendum.

the posterior distribution of λ, the underlying fatality rate parameter for the Poisson distribution that generates *M*. See methods described in the main text of this Appendix.

Prior Distributions

EoA software versions 1.05 through 2.0 (beta), and the analyses presented in this HCP implement a reference prior distribution for $\hat{M}$:

$$Pr(M) \propto \int_{m}^{m+1} \frac{1}{\sqrt{m}}\, dm \tag{2}$$

and a Jeffrey's prior distribution for $\hat{\lambda}$:

$$Pr(\lambda) \propto \frac{1}{\sqrt{\lambda}} \tag{3}$$

Dalthorp and Huso (2015) provide the rationale for choice of these priors, and at present they represent the most robust for general use. In the analyses reported in this Appendix, we called the reference and Jeffery's priors "objective" priors for simplicity. To implement the reference prior for M in JAGS software, we used the dcat function for a general discrete random variable. To implement the Jeffery's prior for λ in JAGS we used a *Pareto*(0.00001, 0.25) distribution which has 0.994 correlation with $\lambda^{-0.5}$.

Estimation of *g:* Overall Probability to Observe a Carcass

A key input to the EoA fatality estimator is the probability to detect a carcass g, given that a carcass has arrived at the facility. Like the choice of priors, the method to estimate g is not a definitive feature of EoA (Huso et al. 2015). Analyses presented and proposed in this document calculate g following the methods in the EoA software version 1.06[6]. The estimate of g is the product of the fraction of turbines searched γ, the probability that a carcass at a searched turbine falls within a searched area a, and the probability that a carcass falling in a searched area persists and is detected by a searcher $\hat{\pi}$. The estimate of $\hat{\pi}$ is derived from several other models: searcher efficiency, the rate at which searcher efficiency changes with subsequent searches, carcass persistence, and carcass arrival phenology. Each component of g is described in turn in the following sections.

<u>Probability that a Carcass Falls within a Searched Area (Truncated Weighted Likelihood Method)</u>

Fatality monitoring protocols may include search plots that are not large enough to capture all carcasses that arrive at turbines. Estimates of g include a component (A, the probability that a carcass at a searched turbine falls within a searched area) that accounts for carcasses that may have fallen outside of searched areas, whether search plots were too small to capture all carcasses, or whether plots were irregularly shaped (such as road and turbine pad plots).

[6] These methods are not formally documented elsewhere but are described here based on a close reading of the EoA software code.

Carcass fall density is not uniform around turbines; rather, the relative density of carcasses nearer to turbines tends to be greater than the relative density of carcasses far from turbines. It is necessary to model the fall distribution of carcasses relative to the turbine mast via distance (hereafter, “distance distribution”) so that the fraction of carcasses that occur within searched areas can be estimated. Modelling the fall distribution of carcasses is complicated because the observed fall distribution is influenced by a finite search radius (the underlying distribution is truncated) and because the observed fall distribution is distorted by unequal detection probability based on carcass distance from turbines. For these reasons, calculating the area correction, A, is complicated.

The area correction A is calculated by estimating the proportion of carcasses expected to fall within searched areas:

$$A = \sum_{k=1}^{r} (H(k|\hat{\theta}) - H(k-1|\hat{\theta}))\sigma_k \tag{6}$$

where r is the maximum searched radius from the turbine, σ_k is the proportion of area searched within the one meter (3-ft-wide) ring with outer radius being *k* and inner radius being *k*-1, H() is the cumulative density function (CDF) for the carcass distance density, and $\hat{\theta}$ is the estimated parameter vector.

The parameter vector θ is estimated by maximizing the truncated weighted likelihood (Khokan et al. 2013),

$$L_T(\theta|\underline{y}) = \prod_{j=1}^{n} (\frac{L((\theta|y_j)}{\int_{I_t} h(u|\theta)du})^{w_j} \tag{7}$$

where h is the probability density function (pdf) for the carcass distance distribution (connected to H()), I_t is the truncation bounds, L() is the likelihood associated with h(), y_j is the distance from the turbine for the jth carcass, and w_j is the weight for the jth carcass. Several different distributions for h() were considered (Gamma, Weibull, Normal, Rayleigh, and Gompertz) and selected was done based on AICc.

Weights are necessary because the distance pattern of observed carcasses is not the same as the distance pattern of carcasses that arrive at the facility. The observed carcass distribution is influenced by characteristics of the search protocol: proportion of area searched may change with distance from the turbine, and if there are multiple search strata with different proportions of area searched around turbines (such as will occur if a site has cleared plots and road-and-pad plots), than the average detection probability may also vary with respect to distance from turbines. The weights adjust the influence of each observation on the fitted distribution by accounting for the relative probabilities (search effort and detection probability) to include observations in the data. By taking the inverse of the product of these probabilities, the influence of individual observations is adjusted to prevent bias associated with inequitable probabilities of detection with respect to distance. The weight for each carcass is

$$w_j = (\hat{\pi}_j \sigma_{k_j} S_j)^{-1} \tag{8}$$

where $\hat{\pi}_j$ is the probability that a carcass persists and is detected on the first search after arrival (details below), σ_{k_j} is the proportion of area searched within the one meter ring at the distance the jth carcass was found, and S_j is the sampling fraction for the jth carcass.

Searcher Efficiency

Searcher efficiency is the probability that a searcher will successfully detect a carcass that is present within the search area during a search.

Searcher efficiency p follows a simple binomial model and is estimated from experimental trials as:

$$\hat{p} = \frac{\text{number of trial carcasses that were detected by searchers}}{\text{number of trial carcasses that were available to searchers}} \tag{9}$$

Change in Searcher Efficiency through Successive Searches

For a given carcass, searcher efficiency is not constant through time, but changes with successive searches. First, carcasses decay and eventually disintegrate as they age. Second, easy-to-see carcasses are more readily detected during earlier searches, meaning that carcasses that remain through subsequent searches tend to be inherently more difficult to see. If searcher efficiency is assumed constant through time, estimates of detection probability will be biased high, and fatality estimates will be biased low, and the converse also holds. Accurate fatality estimates that make best use of the search data require an understanding of how searcher efficiency changes through time.

The multiplicative parameter k describes changing searcher efficiency through time via:

$$p_{j+1} = p_j \times k \tag{10}$$

where p_j is the searcher efficiency on the j^{th} search. Estimating k requires that searcher efficiency trial carcasses be deployed and left in place through multiple searches, and generally requires large numbers of trial carcasses to ensure adequate sample size beyond the first search. When data that track trial carcasses through a number of searches are available, searcher efficiency can be calculated for successive searches (p_j, where j is an index for searches) and k can be estimated using Bayesian or frequentist methods.

Data to estimate k often are not available. Huso et al. (in press) have analyzed bat searcher efficiency data from numerous studies in North America and suggest that in the absence of data, 0.67 is a reasonable value to use for k for bats. A value of 0.67 means that if searcher efficiency is p for a carcass that has been subjected to no previous searches, it will be $p \times 0.67$ for a carcass that has been available for one search (and missed), $p \times 0.67^2$ for a carcass that has been available for two searches (and missed), and so-on.

<u>Carcass Persistence</u>

Not all carcasses that arrive at the facility persist on the landscape long enough to be discovered. Scavengers, agricultural activity, or other forces may remove carcasses before searchers have an opportunity to detect them. The average probability of persistence of a carcass is estimated from an interval-censored survival model (Huso et al. 2012). Given a search interval of length II, the Huso et al. (2012) approach estimates the average probability that a carcass arriving $\{0, 1, 2, \dots, I\}$ days before the search will persist until the search. Assuming carcass persistence times follow a probability distribution $f(d)$ with cumulative probability function $F(d)$, the probability of "survival," or persistence, until day d is $1 - F(d)$. If carcass arrival is uniform in time so that the probability of arrival is constant between 0 and I, the average persistence probability r until the first search after a carcass arrives is:

$$r_{1,1} = \frac{\int_0^I 1 - F(d)\, dd}{I} \tag{11}$$

A minor modification of this formula accommodates carcasses that may be missed on the first search and discovered on a subsequent search (the j^{th} search). The average probability that a carcass which has persisted from the $(j-1)^{th}$ search also persists until the j^{th} search is:

$$r_{1,j} = \frac{\int_{(j-1)\times I}^{j\times I} 1 - F(d)\, dd}{\int_{(j-2)\times I}^{(j-1)\times I} 1 - F(d)\, dd} \tag{12}$$

where $j \geq 2$.

<u>Carcass Arrival Phenology</u>

The detection probability for any particular carcass depends on when it arrives at the facility. This is because carcasses that arrive earlier during the study period have the potential to persist through more searches, and therefore have more opportunities to be discovered, than carcasses arriving later during the study period. Assume that there are q searches during the study period that occur on days $\{d_1, d_2, \dots d_q\}$, and assume there are no carcasses available when the study period begins on day $d_0 = 0$. The time interval $\{d_{i-1}, \dots, d_i$ is the i^{th} arrival interval, and the proportion of carcasses arriving during the i^{th} arrival interval is c_i, where we ensure that all of the carcasses arrive during an interval by ensuring that:

$$\sum_{i=1}^{q} c_i = 1.0 \tag{13}$$

Equality of all of the c_i implies the same relative arrival rate of carcasses between each search interval, i.e., over the entire study period. This would be the case if, for example, the arrival phenology of carcasses is uniform in time and the search interval is constant between searches. The c_i can be adjusted to reflect non-constant arrival phenology, non-constant search interval, or both.

When carcass arrival is pulsed (as it may be if there is a seasonal migration), it is likely that the relative abundance of carcasses during a pulse forms a bell-shaped curve but it is rare to have appropriate data to estimate the shape of the curve. Even with adequate carcass arrival data, large year-to-year variation in phenology precludes the assumption that one year's estimate will be adequate to predict for a subsequent year. Consequently, arrival phenology is assumed to be uniform through the intervals within a season and adjustments to the c_i are made on the basis of relative fatality rates from season to season. If seasonal and annual fatality estimates are not available for the target species of interest, fatality estimates for a larger group of species (e.g. all bats) may be used as a surrogate.

Probability that a Carcass Falling in a Searched Area Persists and is Detected by a Searcher

The probability that a carcass arriving during the i^{th} interval persists and is detected on the i^{th} or subsequent searches (*interval-specific detection probability*) is calculated recursively for each search from i to q, where q is the last search. The probability that a carcass persists and is detected on the first search after arrival is:

$$\pi_{i,i} = r_{i,i} \times p \tag{14}$$

where $r_{i,i}$ is the probability of persistence (equation 12) and p is the probability of detection (equation 10). The probability that the carcass persists and is detected on the second or subsequent searches after arrival is:

$$\pi_{i,j} = \pi_{i,i} + \sum_{\psi=i+1}^{j} (1 - \pi_{i,\psi-1}) \times (r_{i,\psi} \times p \times k^{\psi-i}) \tag{15}$$

where $\pi_{i,j}$ is the probability that a carcass arriving during the i^{th} interval persists and is detected during the j^{th} search and k is the factor by which searcher efficiency changes from one search to the next. For a study with a total of q search intervals, $\pi_{i,j}$ can be calculated for any $0 \leq i \leq j \leq q$, but in practice we are interested in the probability that a carcass arriving during the i^{th} interval is detected at *some* point before the end of the study, i.e. $\pi_{i,q}$.

The first element of the product in the summand of equation (15) represents the probability that the carcass is missed during all previous searches and the second element of the product in the summand of equation (15) represents the probability that the carcass is discovered during the j^{th} search.

The overall probability of detection for a carcass is the average of the interval-specific arrival probabilities weighted by the arrival fraction c_i:

$$\pi = \sum_{i=1}^{q} \pi_{i,q} \times c_i . \qquad (16)$$

Overall Probability of Carcass Detection

For a facility with z search strata having T_z turbines in each of the z, of which t_z are searched, the overall probability that a carcass arriving at the facility will fall in a searched area, remain available for searchers, and be detected is:

$$g = \sum_{i=1}^{z} \frac{t_i}{T_i} \times a_i \times \pi_i \qquad (17)$$

The variance of this estimator is unknown. Bootstrap resampling procedures are used to approximate CIs for this estimator when required.

Single-Site, Single-Year Fatality Estimation with Evidence of Absence Software

The EoA software provides functionality to calculate a fatality estimate for a single site during a single year. The estimating model is exactly as given in the *Model Form* section (above). This module of the EoA software is the only module that calculates g based on user-supplied information about the arrival function, search schedule, probability that a carcass falls in a searched area, searcher efficiency, and carcass persistence, and the form of the information accepted by the software varies by version. Versions 2.0 (beta) and higher return g as the two parameters that describe a beta distribution. Earlier versions return g with 95% CIs, calculated in the *Overall Probability of Detection* section (above).

The EoA software takes the probability of carcass detection g and the count of carcasses from searches X as inputs and returns the posterior distribution of total fatality. Versions 2.0 and later will also return the posterior distribution of the fatality rate, λ.

Multiple Year (or Multiple Season) Fatality Estimation

When data are available from multiple search periods (years or seasons) the EoA software can provide a cumulative estimate of fatality covering the entire search history. The estimating model is exactly as given in the *Model Form* section (above). Inputs to the EoA software are in the form of a matrix with one row for each search period. For versions 1.06 and earlier, the columns contain carcass counts, the point estimate of g, upper and lower 95% confidence bounds for g, and annual weights. For versions 2.0 and later, the columns contain carcass counts, the two parameters of a beta distribution that describe g, and annual weights. The annual weights are proportional to the expected relative fatality rates for each sampling period. Although fatality rates are unknown, weights may vary with facility size (if, for example, a facility doubles in size between two sample periods) or with adaptive management actions (e.g. a facility implements an adaptive management action that is expected to reduce fatality by half). The weights are used to calculate a weighted average g:

$$g = \frac{\sum_{b=1}^{sampling\ periods} g_b \times v_b}{\sum_{b=1}^{sampling\ periods} v_b} \tag{18}$$

where g_b and v_b are the sampling-period-specific probabilities of detection and weights, respectively.

The multiple year module of the EoA software will return an estimate of total cumulative fatality, M, or an estimate of the average fatality rate λ. If λ is returned it carries units of carcasses per facility per sampling period and it is scaled to be relative to a facility operating with a weight of 1.0.

Multiple Site (or Search Stratum) Fatality Estimation

When data are available from multiple sites or multiple search strata within a site, the EoA software can provide a cumulative estimate of fatality covering the entire searched area. The estimating model is exactly as given in the *Model Form* section (above). Inputs to the EoA software are in the form of a matrix with one row for each stratum.

For versions 1.06 and earlier, the columns contain carcass counts, the point estimate of π, upper and lower 95% confidence bounds for π, and stratum weights. For versions 2.0 and later, the columns contain carcass counts, the two parameters of a beta distribution that describe π, and stratum weights.

The stratum weights are the fraction of carcasses that are expected to fall within each search stratum (i.e. a from the *Probability that a Carcass Falls within a Searched Area* section, above). In version 2.0 and later, the stratum weights must sum to 1.0 and the input matrix always includes an *unsearched* stratum (with $\pi = 0$) to account for unsearched turbines or areas.

The weights are used to calculate a weighted average g:

$$g = \sum_{z=1}^{sampling\ strata} \pi_z \times a_z \tag{19}$$

where π_z and a_z are the stratum-specific probabilities of detection and area corrections, respectively.

The multiple site module of the EoA software will return an estimate of total fatality, M, or an estimate of the fatality rate λ. If λ is returned it carries units of carcasses per sampling period and it covers the entire area represented within the input data table.

Selecting Credible Bounds from Evidence of Absence Estimates

Because EoA is a Bayesian model, the estimates it returns are distributions of total take or the take rate and when a single number is needed to set a threshold or determine compliance, it is necessary to select a credible bound from the posterior distribution. There is no objective way to select credible bounds; the decision is based on a subjective assessment of the risks of setting the wrong threshold or being wrong about compliance. In general, the 50th credible bound, or median of the distribution, is a good value to use for a point estimate: we are 50% confident that the true value is not greater than that value. As larger credible bounds are chosen we become more confident that the true value will *not* be larger than our estimate.

Fatality Estimation and Fatality Prediction with Evidence of Absence

Fatality estimation in Evidence of Absence is straightforward: carcass counts and probabilities of detection are analyzed using Evidence of Absence, and a take estimate M is obtained with the desired level of credibility.

It is often desirable to obtain fatality predictions based on past fatality estimates but unless a fatality prediction is desired for the same time interval and the same area that informed the prediction, it is not possible to use the estimate of M in fatality prediction. The estimate of M is specific to the duration, area, and operational regime (i.e. turbine cut-in speed) where the data were collected. An estimate of M that is calculated for a facility with two equally-sized phases cannot be rescaled to represent one phase of the facility. This is because M is a credible bound from a Poisson posterior, and the quantiles of Poisson distributions do not scale in a linear way.

When a fatality prediction is needed, the procedure is to estimate the fatality rate, λ, for a facility that is sufficiently comparable to the facility for which a prediction is desired. Unlike M, the credible bounds of λ can be rescaled to represent larger or smaller facilities, or longer or shorter time periods, or facilities with different operational regimes. For example, if λ is estimated (at a desired level of credibility: Q_λ) for a facility with 100 turbines over a 2-year period and a prediction is needed for a 200-turbine facility for 30 years, the predicted fatality rate (with the same Q_λ) will be $\lambda_{pred} = 2 \times 15 \times \lambda$.

Getting from λ_{pred} to a predicted number of fatalities for the purpose of setting a take authorization number requires the selection of a credible bound (Q_M) for the prediction of M. The predicted number of fatalities is then the Q_M credible bound (= Q_M quantile) from a Poisson distribution with a rate parameter equal to λ_{pred}.

Evidence of Absence for Monitoring Design

The EoA software has a *Design Tradeoffs* module that is useful when designing fatality monitoring. The module calculates g as described above in *Estimation of g: Overall Probability to Observe a Carcass* given user input and returns the results in graphical format.

Table 1. Parameters and indices used in this appendix, which models they inform, and how they are obtained.

Parameter	Definition	How Obtained	Models in Which it is Used
α	One minus the credibility of an estimate	Subjective decision	Fatality estimation
a	proportion of carcasses expected to fall within searched areas	Estimated	Overall probability of detection
b	Index for sampling periods within a multiple-year or multiple-season EoA estimate	Index	EoA fatality estimation
c_i	Fraction of carcasses arriving during the i^{th} i^{th} interval	Assumed uniform within seasons; Estimated among seasons	Overall probability of detection
d	Time (days) to carcass removal	Function input	Carcass persistence
$f(d)$	Probability distribution function for persistence times (d d; days) of carcasses	Estimated	Carcass persistence
$F(d)$	Cumulative distribution function for persistence times (d d; days) of carcasses	Estimated	Carcass persistence
g	Overall probability that a carcass arriving at the facility persists and is detected by searchers	Estimated	Overall probability of detection
g_{ij}	Probability that a carcass arriving during the i^{th} i^{th} interval persists until and is discovered during the j^{th} j^{th} interval, conditional on having persisted until the $j-1^{th}$ $j-1^{th}$ interval	Estimated	Overall probability of detection
γ	Proportion of turbines searched	Known	Overall probability of detection
H_x	Proportion of carcasses in the annulus that covers between $x-1$ $x-1$ and x x meters from turbines	Estimated	Area correction
$h(x\mid\theta)$	Probability distribution function for distances (x x; meters) of carcasses from turbines	Estimated	Distance distribution
$h^{*}(x\mid\theta)$	Truncated probability distribution function for distances (x x; meters) of carcasses from turbines	Estimated	Distance distribution
I	Duration of search interval; number of days between searches	Known	Carcass persistence
i	Index for intervals	Index	Carcass persistence, overall probability of detection
j	Index for searches	Index	Carcass persistence, overall probability of detection
k	Factor by which searcher efficiency (p p) changes between searches	Assumed ($k = 0.67$ $k = 0.67$) or estimated	Overall probability of detection
λ	Fatality rate	Estimated	Model form
M	Total fatality	Estimated	Model form
n	Number of search strata contributing data to the distance distribution ($h^{*}(x\mid\theta)$ $h^{*}(x\mid\theta)$) of carcasses from turbines	Known	Distance distribution of carcasses

Table 1. Parameters and indices used in this appendix, which models they inform, and how they are obtained.

Parameter	Definition	How Obtained	Models in Which it is Used
p	Searcher efficiency; this is the probability that a carcass that is in a search area during a search is detected by a searcher	Estimated	Overall probability of detection
Pr	Abbreviation for *Probability*	Abbreviation	
π	Probability that a carcass within a searched area will be available to searchers and detected	Estimated	Overall probability of detection
Q	Credible bound for estimation or prediction of $\lambda\lambda$ or MM	Subjectively selected	
q	Number of searches and search intervals during the study	Known from field data	Overall probability of detection
r_{ij}	Average probability that a carcass arriving during interval ii persists until search jj	Estimated	Carcass persistence, overall probability of detection
s	Index for carcasses informing the distance distribution	Index	Distance distribution
S	Total number of carcasses informing the distance distribution		Distance distribution
σ_{xz}	Average proportion of area searched between $x-1x-1$ meters and xx meters from the turbine in stratum zz	Estimated in GIS	Distance distribution
T_z	Total number of turbines in sampling stratum zz	Known from field data	Distance distribution
t_z	Number of turbines sampled within a sampling stratum zz	Known from field data	Distance distribution
θ	Parameters associated with the probability distribution function for distances of carcasses from turbines $h(x \mid \theta)h(x \mid \theta)$	Estimated	Distance distribution
$\ddot{\theta}$	Estimated parameters associated with the truncated probability distribution function for distances of carcasses from turbines $h^*(x \mid \theta)h^*(x \mid \theta)$	Estimated	Distance distribution
u	Maximum search distance (meters)	Known from field data	Distance distribution
v	Sampling period weights for a multiple-year or multiple-season EoA estimate	Estimated	Searcher efficiency, overall probability of detection
X	Count of carcasses from monitoring searches	Known from data	Model form
x	Distance (meters) of carcasses from turbines	Function input	Distance distribution
z	Index for search strata	Index	Distance distribution, overall probability of detection

LITERATURE CITED

Dalthorp, D., M. Huso, D. Dail, and J. Kenyon. 2014. Evidence of Absence Software User Guide. US Geological Survey (USGS) Data Series 881. USGS, Reston Virginia. September 19, 2014. Available online at: http://pubs.usgs.gov/ds/ 0881/pdf/ds881.pdf

Dalthorp, D. and M. Huso. 2015. A Framework for Decision Points to Trigger Adaptive Management Actions in Long-Term Incidental Take Permits: U.S. Geological Survey (USGS) Open-File Report 2015-1227. 88 pp. Available online at: http://dx.doi.org/10.3133/ofr20151227

Huso M, N. Som, and L. Ladd. 2012. Fatality Estimator User's Guide. U.S. Geological Survey (USGS) Data Series 729. 22 pp. December 12, 2012.

Huso, M., N. Som, and L. Ladd. 2015. Fatality Estimator User's Guide. US Geological Survey (USGS) Data Series 729. Version 1.1. December 2015. Available online at: http://pubs.usgs.gov/ds/729/pdf/ds729.pdf

Huso, M., D. Dalthorp, and F. Korner-Nievergelt (In press). Statistical Principles of Post-Construction Fatality Monitoring Design. *In*: Perrow, M., ed. Wildlife and Wind Farms, Conflicts and Solutions, Volume 2, Onshore: Monitoring and Mitigation. Pelagic Publishing, Exeter, U.K.

Khokan, M. R., W. Bari, and J. A. Khan. 2013. Weighted Maximum Likelihood Approach for Robust Estimation: Weibull Model. Dhaka University Journal of Science 61(2): 153-156.0