SUMMARY REPORT

Peer Review of the Scientific Findings in the U.S. Fish and Wildlife Service Eagle Fatality Model and its Application to Wind Energy Development Projects

DIVISION OF MIGRATORY BIRDS

REGION 6 OFFICE

U.S. FISH AND WILDLIFE SERVICE

March 14, 2013

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USFWS Order No. F13PB00058
AMEC Project No. 32106C001

TABLE OF CONTENTS

Executive Summary 1
1.0 Background 4
2.0 Peer Reviewer Approach 5
2.1 Description of Individual Reviewer's Role 5
2.2 Model Development and Description 6
2.3 Thousand Turbine Project (TTP) 8
2.4 PWRC Power Turbine Model Methods and Outputs 9
3.0 Summary of Peer Review Responses 9
3.1 General Model Review Questions 10
3.2 1000 Turbine Project Peer Review Questions 14
3.3 90 Turbine Project Peer Review Questions 17
3.4 Other Review Questions and Comments 18
4.0 Overall Summary for Each Individual Reviewer 19
Reviewer 1 19
Reviewer 2 19
Reviewer 3 20
Reviewer 4 20
5.0 Conclusions and Recommendations 21

Appendix A: Model Output
Appendix B: Complete Reviewer's Responses
Appendix C: Reviewer's Resumes
Appendix D: Webinar Agenda, Presentation and Minutes

Executive Summary

The U.S. Fish and Wildlife Service (Service) wishes to develop a scientifically valid and robust model to predict bald and golden eagle fatalities at wind energy facilities. The Service developed a Bayesian model and requested an external scientific peer review to examine the model's scientific merit, assumptions, and statistical rigor while applying it to a 1000 turbine wind energy project and a 90 turbine project.

For the most part, the model received positive comments with respect to its general applicability and was considered to be scientifically and statistically valid in its purpose of defining the relationship between eagle exposure, collision probability, and fatalities, given adequate datasets are available to feed the model. The emphasis on adaptive management and use of iterative Bayesian modeling was considered to be a strong point given the inherent uncertainties involved in trying to predict birds' responses to turbines and the poorly understood factors that influence collision probabilities. Although several concerns were raised (discussed below and see Appendix B for complete reviews), the reviewers praised the conservativeness of the model because it does not over-extend its intended purpose of predicting eagle fatalities while using the limited data resources that are currently available. Reviewer 4 urged caution in the use of this model for large scale facilities, such as the 1000 turbine case study, where the non-linear effects are much more difficult to predict at this time.

Some general concerns in the model's effectiveness surrounded the availability of adequate data or the ability to collect adequate data that captures variability in eagle behavior both spatially and temporally. Reviewer 1 also expressed some concern with using the Poisson distribution to model eagle minutes and fatalities because the Poisson distribution likely underestimates variability and in this case, violates the assumption of independence (bird behavior may not be independent). By rewriting the model in R and OpenBugs, Reviewer 1 suggested that the Poisson distribution assumptions could be relaxed (i.e. move to a Negative-Binomial model) to incorporate additional variation by modeling individual exposure and fatality data on a year-by-year basis rather than relying on summary data.

Reviewers 2, 3 and 4 believed that rather than pooling the data across a site it would be more appropriate to stratify the data in biologically relevant seasons (breeding, migration, and non-breeding), topography, wind speeds, between resident and migrant eagles, and by eagle age (an investigation into age class collision probabilities was recommended). Reviewer 4 was concerned that scale effects are not considered, nor are the effects of construction and monitoring on eagle behavior.

Reviewers assessed the model's assumptions and communicated that the following assumptions needed to be strengthened or clarified in order to validate the utility of the model:

- Eagle minutes follow a Poisson distribution;
- All eagle minutes are the same, regardless of breeding status and with equal demographic consequences, and are independent of density;

- Pre-construction eagle incursions and post-construction fatalities are statistically independent;
- Eagle exposure rate is uniform across a stratum;
- Following an eagle mortality, replacement is instantaneous and equal;
- There is no age structure within the population (or there is no differential risk among age classes);
- There is no differential risk experienced by successful breeders versus failed or non-breeders and by resident birds versus migrants; and,
- There is no differential risk between turbine locations within a project site, nor between the number of turbines between sites (project scale effects).

Reviewer 4 stressed that despite perceived issues in the validity of these assumptions, altering them would call for even more caution and more conservative decision making in predicting fatality rates.

While Reviewer 3 found no programming errors in the model program files in R code, Reviewer 1 believed the R code had many potential errors and invalid methods, and provided a 'corrected' model. Reviewer 1 also felt that rewriting the model in a combination of R and OpenBugs would relax the Poisson distribution assumption, allow modeling of the individual exposure and fatality data on a year-by-year basis rather than relying on the summary data, and thus would provide more flexibility in the variance-to-mean ratio. Reviewer 1 also believed that the percentiles for the 5 year prediction outcome could not be calculated by multiplying the corresponding percentile from a 1 year prediction by 5.

Summary of the model's limitations:

- The use of the Poisson distribution assumption underestimates the number of fatalities and does not fully account for the inherent variability in the process;
- The eagle minutes of exposure also underestimates the model's variability;
- The model assumes that all eagle events occur independently (a Poisson distribution assumption); however, eagle behaviors may not be independent;
- When input data are insufficient, the model is likely producing invalid results;
- The model is only useful for each site if project proponents gather adequate data that do not violate model assumptions;
- The model does not account for potential differential risk among age classes;
- The model may be too simple for large scale purposes where non-linear scale effects are not easily assessed; and,
- The available data for the 1000 Turbine Project is inadequate for use in the model and the current data violate the assumptions that pre-construction eagle use data are spatially and temporally representative of the stratum and that the eagle exposure rate is uniform across a stratum.

Summary of suggestions for improving the model:

- Adopt a more clear Bayesian perspective by clearly identifying each part of the data (e.g. pre-construction eagle minutes; post construction eagle mortalities; the likelihood for each piece of data; the prior distribution for each parameter in the likelihoods, etc;
- Identify and address data deficiencies and find mechanisms to improve parameter estimates;
- Use point count data to provide information on the variability in the eagle minutes of exposure that is not captured by the Poisson distribution;
- Collect data across several spatial and temporal stratum especially for large projects, as research indicates that fatalities vary by turbine location and by season;
- Ensure that point count locations provide thorough sampling coverage across the project site, preferably using a stratified random design that incorporates habitat type, topography and avoidance areas;
- Conduct equal sampling among seasons and define seasons based on eagle behaviors;
- Nest sites found within the project area should be included in representative surveys and random surveys should be conducted to investigate use of the site area by non-breeding eagles;
- Use telemetry to gather information on eagle movement through existing projects;
- Incorporate probability estimates for collision risks to eagles of different age groups, different breeding status, and between migrants and residents;
- Model the distribution of waiting times between individual events and the distribution in transit times which would result in modeling fatality risks as a hazard function related to the duration of the visit;
- Incorporate temporal variation in mortality if high-risk events, such as inclement weather and visibility which could potentially cause high (or low) mortality events;
- Record eagle minutes during both high and low-risk events;
- Address various concerns about assumptions;
- Rewrite the model in a combination of R and OpenBugs to provide more flexibility in the variance-to-mean ratio (thus avoiding the assumption that there is no closed form posterior and relaxing the Poisson distribution assumption);
- Model the individual exposure and fatality data on a year-by-year basis rather than relying on the summary data;
- Model fatality risk as a hazard function related to the duration of eagle visits,
- Add sensitivity or elasticity analysis;
- Improve the priors for fatality estimates (i.e. post-construction adjustments should include scavenger removal estimates of eagle carcasses to determine annual fatalities); and,
- Build in non-linear scale effects.

1.0 Background

As part of the U.S. Fish and Wildlife Service (Service) Eagle Conservation Plan Guidance (ECPG), the Service developed a Bayesian model to predict the annual fatality rate for bald and golden eagles at a given wind energy facility. This Service model defines the relationship between eagle exposure, collision probability, and fatalities, while accounting for uncertainties. The Service model is intended to provide a foundation for modeling fatality predictions from eagle exposure to hazards posed by wind turbines, because the actual relationships among eagle abundance, fatalities, and their interactions with factors that influence collision probability are still poorly understood. Further, the Service model serves as a basis for learning (i.e., an adaptive framework) and should provide a conservative benchmark when exploring other candidate models that attempt to incorporate additional variables and complexity. Through an adaptive management framework, the intent is to refine the Service model with updates and improvements over time.

Given both the current and future use of the Service eagle fatality model to predict both bald and golden eagle fatalities associated with proposed wind energy development projects throughout the U.S., the model and its application in predicting eagle fatalities would benefit from a formal, external, independent, scientific peer review to assess both its scientific validity and whether the Service is using it in an appropriate and unbiased manner as applied to both large and small wind energy projects. The Service desires to use the most scientifically valid and robust model in predicting eagle fatalities at wind energy facilities and to ensure the model is appropriately applied. Therefore, if the peer review demonstrates ways in which the existing model can be improved, this outcome is of great benefit to the Service.

The purpose of this review was to provide a formal, independent, external scientific peer review of the U.S. Fish and Wildlife Service (Service) eagle model for predicting fatalities at wind energy facilities in the U.S., and the application of this model to a proposed 1000 turbine wind project and a second, smaller, more typical, 90 turbine wind project. The Service provided the following documents and data to be used during the peer review:

- Draft Eagle Conservation Plan Guidance (ECPG), 2011
- Draft ECPG Technical Appendices, 2012
- Draft ECPG Summary Sheet, 2011
- Draft ECPG Questions and Answers, 2011
- Draft Service Baseline Collision Model, Modeling Framework Details and Assumptions
- R Code for the Service Model
- 90 Turbine Data and Maps
- 1000 Turbine Data and Maps

2.0 Peer Reviewer Approach

The reviewers assessed the approach and assumptions the Service used in developing the eagle fatality model. In order to meet the Service's objectives of this review, the reviewers addressed the following:

- The scientific merit, assumptions, and statistical rigor of the eagle fatality model itself, providing the basis for annual eagle fatality predictions at individual project sites;

- The application of the model to a proposed 1000 turbine wind energy project given available data and the juxtaposition of this project within its respective landscape and the application of the model to a smaller, more typical, 90 wind turbine project; and,

- Each reviewer ensured that any scientific uncertainties (or data insufficiencies) were clearly identified and characterized, and the potential implications of the uncertainties for the technical conclusions drawn were clear.

Each modeling reviewer conducted the model review independently using the data and R code provided by the Service. Results of the modelers' assessment of the model and its assumptions, along with outputs of the two scenarios including real data from a 1000 turbine project (TTP) and simulated data for a smaller 90 turbine project were then shared with the rest of the reviewers. After the initial review process was completed, all four reviewers later interacted and examined eagle risk and impacts to produce the overall review. During the follow-up question phase, the Service will have an additional opportunity to pose questions to individual reviewers or the reviewers collectively as a team.

2.1 Description of Individual Reviewer's Role

Four independent, unbiased, scientific reviews of the Service's eagle model and two scenario data sets were undertaken. Two of the reviewers are biometricians and modelers who focused on running the model, its construction, components, program code and assumptions. The remaining two reviewers are ecologists with extensive experience on eagle biology and behavior. Their review was focused on the model outputs and their implications for eagles, eagle populations, impacts and risks to eagles with respect to the two project scenarios (1000 turbine and 90 turbine projects).

The independent peer reviewers are all experienced, senior-level raptor/eagle experts and/or biometricians/ecological modelers who have previously conducted similar reviews and are familiar with the statistical package "R". The reviewers are all independent of the Service, US Geological Survey (USGS), SWCA consulting firm, and are not directly employed by wind energy companies or working on any aspect of the aforementioned 1000 wind turbine project in Wyoming. The resumes for the peer reviewers are presented in Appendix C and the panel members consist of:

- Bryan Bedrosian from Craighead Beringia South;

- Todd Katzner, PhD from West Virginia University;
- Timothy Keitt, PhD from University of Texas at Austin; and
- Carl Schwarz, PhD from Simon Frasier University.

2.2 Model Development and Description

The Service held a Webinar led by the Service's Eagle Technical Assessment Team (ETAT) to provide the background on the purpose and development of the model, as well as the datasets for this peer review. The Webinar was held on January 28, 2013 from 12:30 – 2:30 pm (Mountain) and the slides and minutes from the Webinar are included in Appendix D. The ETAT initially reviewed existing models for predicting take of eagles and other raptors at facilities. No existing model was strongly supported so the team took elements of existing models and developed a new model specifically for Service use. The main hurdle in creating the model was uncertainties on several important parameters including the population status of golden eagles, population level risk due to wind farm mortalities, factors that influence risk created by wind farms and ways of minimizing risk. Additionally, under the currently existing Eagle Permit Rule, the Service cannot require collection of specific data or use of a specific model by a proponent, but can make recommendations. This is recognized as a limitation for model development and model evaluation. Data to undertake meta-analyses considering site-specific factors that may influence risk (i.e., consistency across sites) in an adaptive management context is currently difficult.

The Bayesian model approach was chosen because of the lack of data and the level of uncertainty on a number of factors. The original model incorporated data from 11 facilities into a mixture model that was used to inform the prior distribution for one of the model parameters (exposure rate). It is a simple model comprised of three factors:

*Collision Fatalities = Exposure Rate * Collision Probability * $\mathcal{E}$ (Expansion Term)*

The collision prior variable is based on the best available public data for avoidance from Whitfield (2009). The Service plans to update this variable once better data is available. The collision posterior distribution assumes fatality data come from a binomial distribution and assumes known fatalities. Currently a project is underway to determine unbiased estimates of carcass abundance at wind turbine facilities. These estimates, based on post-construction mortality data, and their associated uncertainty will then be incorporated in the Service's model to update collision probability.. Exposure is measured by eagle minutes and is modeled using a Poisson distribution. The expansion term is the hazardous area based on rotor size and number of turbines. Daylight hours were also incorporated into the model and can be modified to reflect operational reality regarding turbine hours.

2.2.1 Model Assumptions

Baseline Collision Model and Modeling Framework Details and Assumptions:

- All eagle collisions with wind turbines remove the bird from the population;

- Eagles are only at risk of colliding with turbines during daylight hours (flight in proximity to turbines does not occur during non-daylight hours). This can be specified further on a project-by-project basis where there are supporting data; and,
- Open population – eagles move between project site and surrounding areas, therefore the removal of an eagle does not result in a permanent change in eagle abundance.

Exposure:

- Pre-construction eagle use data used to estimate eagle exposure are spatially and temporally representative of the stratum (or project if strata are not identified). Eagle exposure is eagle flight time in the project footprint per unit area per unit time;
- There is a predictable relationship between pre-construction eagle exposure and subsequent fatalities with a given amount of hazardous area around turbines. The project footprint is the minimum-convex hull that encompasses the wind-project area inclusive of the hazardous area around all turbines and any associated utility infrastructure;
- The prior distribution Gamma (0.97, 2.76) is appropriate for describing exposure rate and includes the range of possible exposure rates at potential sites;
- Eagle flight minutes observed in the project footprint follow a Poisson or similar distribution. This could be modified where appropriate given the data; and
- Eagle exposure rate is uniform across a stratum (or project if strata are not identified).

Collision Probability:

- There is a predictable relationship between the hazardous area around a turbine and subsequent fatalities given an exposure rate. Hazardous area is the 2-dimensional rotor-swept area around a turbine or proposed turbine;
- The prior collision probability Beta (1.2, 176.7) is appropriate for collision probability and includes the range of possible collision probabilities across sites and various risk scenarios; and,
- The collision probability is uniform for all hazardous area and among turbines within a stratum (or project if strata are not identified).

Fatality Rate:

- The fatality rate is constant for all hazardous area within a given stratum (or project if strata are not identified); and,
- The fatality rate is constant for a temporal/seasonal stratum (or all time periods if strata are not identified).

2.2.2 Sample Project Model Methods and Outputs

Models were run separately by each model reviewer. Reviewer 1 made minor modifications to the R code so that a single .pdf file was created for all output rather than separate portions of output being sent to the R console and a separate plot, the model was run as-is for both 90 and 1000 turbine projects. Reviewer 2 made minor modifications to file system paths and output

formatting, the model was run as-is for both the 1000 and 90 turbine Projects. Both reviewers also ran the models with increased daylight hours to capture dawn and dusk, as requested by the eagle biologists. The model output is provided in Appendix A.

2.3 Thousand Turbine Project (TTP)

For the 1000 turbine proposed project, Reviewer 1 and Reviewer 2 ran the model as provided and also with increased (4818.03) daylight hours to capture dawn and dusk. Both reviewers also ran the model twice utilizing different sample zones; the first run included all of the sampled area, including raptor exclusion zones, the second run utilized a reduced sample area that avoided raptor exclusion zones.

Methods to include the raptor exclusion zone were provided by the Service. An intersection between the 800 meter point counts and the TTP proposed avoidance areas was created in ArcMap 10. For each golden eagle observation in geospatial data, a comparison of the date and distance in the attribute table with the date and distance in the Excel spreadsheet was performed to determine if the eagle minutes in the Excel spreadsheet fell inside or outside of the proposed avoidance areas. Eagle minutes falling within the proposed avoidance areas were subtracted from the total eagle minutes of the respective 800 m point count. The revised eagle minutes were then used to rerun the eagle fatality model to account for the proposed avoidance areas. To adjust the area surveyed, the area within the intersection of the 800 m point count and the TTP proposed avoidance areas was calculated in ArcMap 10 and then subtracted from the area of an 800 m point count (2.01 km^2). To incorporate the revised point count areas into the eagle fatality model, the average radius from the sum of the areas of the 15 point counts was calculated:

Average Radius = ((((21.277 km^2 /15)/3.14159)^0.5)*1000) = 672 meters.

The 80th quantile is the number of collisions used to predict fatalities at a given project. For this proposed project, 300 eagle fatalities are predicted over 5 years using the entire sample area including the raptor avoidance area (Table 1). If the raptor avoidance area is removed from the analysis, 260 eagle fatalities are predicted over 5 years (Table 1). If the number of daylight hours is increased to account for eagle activity at dusk/longer days to 4673.48, then 330 eagle fatalities are predicted over 5 years without avoidance of the raptor area (Table 1). If the number of daylight hours is increased but the raptor area is avoided, the number of fatalities drops to 275 eagles over 5 years.

Table 1: Annual Estimate Summary of TPP Model Output for Each Model Reviewer

	Mean	SD	50th	80th	90th	95th
Modeler 1 - avoid raptor area (438 eagle-min; 4324.26 daylight hours)	33	30	24	52	72	91
Modeler 1 - with raptor area (729 eagle-min; 4324.26 daylight hours)	38	35	28	60	84	107
Modeler 1 – avoid raptor area (438 eagle-min; 4673.48 daylight hours)	35	32	26	55	77	99
Modeler 1 - with raptor area (729 eagle-min; 4673.48 daylight hours)	41	38	31	66	91	116
Modeler 2 - avoid raptor area (438 eagle-min; 4324.26 daylight hours)	33	30	24	52	72	92

Modeler 2 - with raptor area (729 eagle-min; 4324.26 daylight hours)	38	35	28	60	84	107
Modeler 2 - with raptor area (729 eagle-min; 4673.48 daylight hours)	41	38	31	66	91	116

2.4 90 Turbine Model Methods and Outputs

For the PWRC Power adjusted 90 turbine sample project, one reviewer ran the model twice; a discrepancy of one Eagle-minute between the webinar presentation of observed eagle minutes and that listed in the actual code (PWRC_CMData3.R file) was noted. The model was subsequently re-run using 36 observed eagle minutes to match the information presented in the webinar (Table 2). Reviewer 2 ran the model twice; for the second run the daylight hours were increased to 4818.03 to include twilight hours (Table 2).

The 80th quantile is the number of collisions used to predict fatalities at a given project. For this sample project, 22 eagle fatalities are predicted over 5 years using 4454.3 daylight hours as input to the model. If the number of daylight hours is increased to account for eagle activity at dusk/longer days to 4818.03, then 24 eagle fatalities are predicted over 5 years (Table 2). The small change to eagle minutes had very little impact on predicted collisions.

Table 2: Annual Estimate Summary of PWRC 90 Turbine Model Output for Each Model Reviewer

	Mean	SD	50th	80th	90th	95th
Modeler 1 (35 eagle minutes; 4454.30 daylight hours)	2.8	2.6	2.0	4.4	6.1	7.9
Modeler 1 (36 eagle minutes; 4818.03 daylight hours)	3.1	2.9	2.2	4.8	6.8	8.7
Modeler 2 (35 eagle minutes; 4454.30 daylight hours)	2.8	2.7	2.0	4.4	6.3	8.1
Modeler 2 (36 eagle minutes; 4818.03 daylight hours)	3.1	2.9	2.2	4.8	6.8	8.7

3.0 Summary of Peer Review Responses

The peer reviewers considered and responded to the questions listed below (from executed award), at a minimum, in their reviews. The following section summarizes their responses, with their full responses provided in Appendix B. Table 3 below provides a quick summary of whether a reviewer provided a response, followed by a summary of each response by question. Answers with 'No Response' indicate the reviewer did not feel themselves qualified to respond to that particular question. For example, raptor biologists did not feel qualified to comment on how the model was coded.

Table 3: Reviewer Response to Each Question

	Reviewer			
	1	2	3	4
General Model Review Questions				
1	Yes	Yes	Yes	Yes
2	No	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes
4	Yes	No	Yes	No
5	Yes	Yes	Yes	Yes
6	No	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes

1000 Turbine Review Questions				
1	No	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	No	Yes	Yes	Yes
4	No	Yes	Yes	Yes
90 Turbine Review Questions				
1	Yes	Yes	Yes	Yes
2	No	Yes	Yes	Yes
3	No	Yes	Yes	Yes

3.1 General Model Review Questions

1. *Is the Service eagle fatality model for predicting eagle fatalities at wind energy facilities a scientifically and statistically valid approach for this intended purpose?*

- Reviewer 1: The Bayesian approach is a sensible way to proceed given the obstacles in predicting outcomes. There is some concern however with using the Poisson distribution to model eagle minutes and Fatalities because it may not account for all variability in the process.

- Reviewer 2: The model is scientifically valid for the given purpose if adequate data are collected in a way that captures the variability of eagle use across seasonal and spatial strata.

- Reviewer 3: The model is sound in spite of the inherent limitations of the available data. The use of adaptive management and Bayesian modeling are strong points.

- Reviewer 4: In general the model is appropriately cautious and notable for generally using some of the best available information on risk. There are some concerns about the model and its implementation generally and in specific that are discussed in answers below.

2. *Is the Service eagle fatality model based upon the best available science? If any instances are found where the best available science was not used, please provide the specifics of each situation.*

- Reviewer 1: No Response.

- Reviewer 2: The only instance of deviation from use of the best available science is associated with assuming the predictable relationship between pre-construction eagle-exposure and post-construction fatalities. Available literature differs with some research finding displacement of eagles and others unable to find a correlation. Age may play a role in the displacement of eagles due to wind farms, but not much research exists on the topic. This may be an easy addition to the model if priors indicate age has an impact.

- Reviewer 3: The model adequately predicts outcomes and is conservative by not making assumptions with limited data resources.

- Reviewer 4: Yes, however, there are a number of characteristics of the natural history of golden eagles that may cause this model to underestimate effects on eagle populations. The bulk of the citations in the eagle review and explanation for the model are based on literature that is a few years old.

3. *Are the methods and assumptions that underlie the Service eagle model clearly stated and logical? If not, please identify the specific methods and assumptions that are unclear or illogical. Also, are these methods and assumptions based on the best available scientific information?*

- Reviewer 1: Appendix D needs to be strengthened and clarified. Specifically, the Poisson distribution assumption also assumes a constant variance-mean ratio and neither this nor its potential consequences were mentioned. The assumption of independence between eagle incursions pre-construction and fatalities post-construction was not detailed enough; the entire model should be presented in a directed graph.

- Reviewer 2: Most of the assumptions made are valid, but several need to be revisited. In particular, stratifying the data in biologically relevant seasons (breeding, migration, and non-breeding), topography, wind speeds, local and migrant eagles, and by eagle age would be more appropriate than pooling the data across the site. An investigation of age class collision probabilities is strongly encouraged. Also, it is important to define daylight hours to include twilight as eagles have been known to forage during these times.

- Reviewer 3: All assumptions are clearly stated and logical except for the assumption that eagle minutes follow a Poisson distribution.

- Reviewer 4: Yes, although there are several assumptions that could be better explored and these are discussed in detail (see Appendix B) including: 1) The assumption of no age structure in the population, 2) the model assumes that all eagle minutes are the same and demographic consequences are independent of density, 3) the model assumes that replacement is instantaneous and equal, 4) scale effects are not considered, 5) cumulative effects are not considered and 6) construction and monitoring effects.

4. *Are the model program files in R code used to calculate the Service eagle model results accurate? If not, please identify any programming errors and the specifics of each error.*

- Reviewer 1: The model is a reasonable approximation given the uncertainties; however there are several areas in which the model can be improved. First, a clear Bayesian

perspective must be adopted. Second, the model should be rewritten in a combination of R and OpenBugs because of the assumption that there is no closed form posterior for the current corrected model. Third, there is useful information in the exposure and fatalities studies that is not being used because the Poisson distribution assumption only requires summary data to update the priors. Fourth, the 5 year prediction outcome from multiplying a 1 year prediction by 5 is correct for the mean, but incorrect for percentiles. Last, the R code must be reviewed and reformulated due to many potential errors and invalid methods.

- Reviewer 2: No Response.
- Reviewer 3: There are no programming errors.
- Reviewer 4: No Response.

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5. *How can the Service model be improved? Please identify any options to strengthen the scientific foundations of the model.*

- Reviewer 1: Use the individual point count data to provide information on the variability in the eagle minutes of exposure that is not captured by the Poisson distribution.
- Reviewer 2: USFWS should mandate the use of several strata in datasets (as described in individual comments in Appendix B), especially for large projects, while recognizing that datasets from project proponents may be insufficient to run the model, under current limitations to require specific data/methods from a proponent. It would be best to identify data deficiencies rather than attempting to run the model on data that will produce inconsistent and possibly erroneous results. A sliding scale of model output certainty correlated with data received could be used to encourage proponents to gather more data. Additionally, different estimates for collision risks to eagles of different age groups should be incorporated into the model.
- Reviewer 3: One improvement would be to model the distribution of waiting times between individual events and the distribution in transit times. This would result in modeling fatality risk as a hazard function related to the duration of the eagle visit.
- Reviewer 4: There are some improvements that could be made including addressing concerns about assumptions in previous questions, adding sensitivity or elasticity analysis and improving the priors for fatality estimates.

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6. *Are there any significant peer-reviewed scientific papers that relate to the assumptions of the Service eagle model where consideration of these papers would enhance the scientific*

quality of the model? Please identify any such peer-reviewed papers and state specifically why incorporation of these ideas would improve the Service model.

- Reviewer 1: No Response.

- Reviewer 2: A more updated method for estimating collision risk can be found in Eichhorn *et al.,* 2012. This paper builds upon the collision risk model by Whitfield and Madders by incorporating both habitat quality and nest locations; two pieces missing from the current model.

- Reviewer 3: A study of griffon vultures by Lucas *et al*. 2012 indicates collision risk is dissimilar between turbines due to location in the landscape and movement pathways and is worth consideration although the species studied is not the same.

- Reviewer 4: There are only a few papers, including some recent papers on risk at wind farms from Spain, eagle flight behavior from eastern North America, work on lead poisoning and the threat it presents and a few papers on the consequences for local population size of killing dominant predators. They would help the model because they would better represent the true population dynamics at this site. See Goodrich & Buskirk, Cons. Bio 1995, 9(6):1357-1364.

7. *Are there any specific improvements or changes to the Service eagle model that would improve our ability to predict eagle fatalities at wind facilities? Please identify (1) what these changes would be to strengthen the scientific foundation of the model, and (2) any peer-reviewed scientific literature to support these suggested improvements or changes. In responding to this question please bear in mind that the Service does not have the latitude to require wind project proponents to collect the exact type or amount of data we would like in order to run the model, nor to specify the exact methods used to collect these data. Hence, the Service model represents a balancing act that approaches the overall issue more generally, resulting in a model that has fewer parameters than would be ideal.*

- Reviewer 1: The Poisson distribution assumption underestimates the number of fatalities and the eagle minutes of exposure underestimates the variability. The individual point count data and yearly records should be used instead to verify the variance-mean relationship and to verify if the use of the Poisson distribution is appropriate.

- Reviewer 2: There should be minimum dataset requirements for those applying for take permits and tangible incentives should be provided to encourage project proponents to acquire the most appropriate and thorough data for their proposed project sites. The Service could adopt a minimum set of criterion for surveys to be used in the model. This minimum could be based on survey guidelines already published by the Service. Additionally, the model is only useful for each site if project proponents gather adequate data that do not violate model assumptions. Lastly, attempts to use the model on a national/regional scale to

evaluate population level effects may be feasible if none of the data violate assumptions, but this model is generally too over-simplified for that purpose.

- Reviewer 3: Research indicates turbines in various positions and contexts within the landscape present different risks for raptors and it could improve the model if such variation in risk was incorporated into the model. Another change could be to incorporate high-risk events such as inclement weather and visibility, which potentially could cause temporal variation and/or elevated risk events. Recording of eagle minutes must represent both high and low-risk events. Additionally, it would be ideal to use telemetry to gather information on eagle movement through existing projects.

- Reviewer 4: Changes as already noted with sensitivity analysis being important. It would also be valuable to find mechanisms to improve parameter estimates.

3.2 1000 Turbine Project Peer Review Questions

Answer these questions with respect to applying the Service model to a proposed 1000 wind turbine project in south central Wyoming.

1. *Was the Service application of the eagle fatality model for the proposed 1000 turbine wind energy project accurate and scientifically unbiased given available data? Are the assumptions in the Service model applicable to the project and its juxtaposition within the landscape? If not please explain specific changes the Service should make in applying the eagle model, including its assumptions.*

- Reviewer 1: No Response.

- Reviewer 2: Given the available data, the Service should not have applied the model to the 1000 turbine project. The data violate the assumptions that pre-construction eagle use data are spatially and temporally representative of the stratum and that the eagle exposure rate is uniform across a stratum.

- Reviewer 3: The model was applied accurately and without bias and the assumptions of the model are applicable.

- Reviewer 4: I feel that the application of the model is accurate and unbiased to the reasonable extent possible given the available data. It would be useful to predict risk more effectively by collecting better flight information on the eagles at this site. I think that the model probably does a poor job of scaling up to large facilities and it is entirely likely that demographic impact will be higher than the model predicts, given the current input data. Understanding the consequences of violations of assumptions would be important to predicting consequences to eagle populations from mortality from this facility.

---

2. *Please assess the eagle use survey data provided to the Service by the proponents of the proposed 1000 turbine wind energy project, for use in running the eagle model to predict annual eagle fatalities at the project site. Given the size of the project footprint, is the available data sufficient to assess potential eagle impacts? If not, in your expert opinion what additional data is both spatially and temporally necessary for use in running the eagle model to best predict annual eagle fatalities? What are the scientific consequences of lacking such data in the analysis?*

- Reviewer 1: The calculation of the "effective radius" covers essentially the same areas as the point counts once the avoidance areas are removed and also has a higher chance of error if done hastily. Instead of this method, simply use the areas directly in the model rather than assuming all point counts are circular and completely covered.

- Reviewer 2: There is a significant lack of data gathered from this project site. First, there is inadequate coverage of the project site. Second, the temporal seasonal survey classifications are arbitrary and do not reflect eagle biology. Last, the point count coverage does not, nor cannot, assess use probability from the highest risk category of eagles and nesting birds with the given survey method.

- Reviewer 3: There is a lack of sampling near the north boundary Site B and adding 2-3 survey sites would give better coverage and sampling.

- Reviewer 4: The data appear inadequate to assess potential eagle impacts. First, there is a difference in the number of observation minutes conducted in each season. Second, there were differences in the mean number of eagles observed per minute in each season. A complete and sufficient data set would have more equal sampling among seasons and, more importantly, constant and reasonable variances and coefficients of variation. The current data set cannot be used to interpret intra-seasonal variability because there is too much variation in the amount of time spent collecting data.

---

3. *What would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers related to eagle behavior or ecology, as they relate to model assumptions, and model application on a project of this scope.*

- Reviewer 1: No Response.

- Reviewer 2: The project areas need better survey coverage, both spatially and temporally. The input data are insufficient and therefore the model will produce invalid results. To correct some issues, nest sites found within the project area should be included in representative surveys, random surveys should be included to investigate non-breeding eagle use, and nest sites should be protected for 30 years to account for reuse over time.

- Reviewer 3: The outcomes could be enhanced by embedding decisions about the project in the large encompassing landscape. Studies such as Fargione *et al*. (2012) where a landscape and regional approach is taken to tradeoff wind power generation with exposure risk may not be as useful for individual species but provide information about larger scale systems.

- Reviewer 4: A more temporally effective sampling and sensitivity analysis.

4. *There are other existing and proposed wind energy facilities within the same local area population of golden eagles where the proposed 1000 turbine project would be developed. The landscape in which the 1000 turbine wind project is proposed is highly rated in terms of its wind energy potential and is used by eagles for breeding, wintering, and migration. Given this backdrop, what scientific factors should the Service consider when assessing potential impacts to eagle populations?*

- Reviewer 1: No Response.

- Reviewer 2: The model assumes an open population of eagles and because of this, the service should look at the 1000 turbine project in addition to existing and proposed wind projects within the general landscape. Two major eagle migration corridors exist within North America; any wind energy sites constructed in migratory routes should be considered when at similar latitudes, because any obstruction to sites along flyways may have an impact on other sites within that same flyway. Additionally, breeding populations can be separated out by BCRs (bird conservation regions) and breeding stratum can be inclusive of all projects within a single BCR.

- Reviewer 3: Landscape-scale risk assessment should consider natural land cover, human land uses, eagle habitat use, and eagle movement patterns, all of which will help improve the basis for decision making.

- Reviewer 4: The impact of the 1000 turbine project is likely to be large. However, even a massive project such as this may have limited demographic impact if mortality it causes is compensatory. If there are additional wind turbines in the region of the 1000 turbine project then the chances are good that mortality there would go beyond compensatory into the additive range and result in population decline. Cumulative effects go beyond those of any one project and I would strongly encourage the Service to consider seriously and implement mitigation for cumulative effects in their permitting process.

3.3 90 Turbine Project Peer Review Questions

Answer these questions with respect to applying the Service model to a proposed 90 wind turbine project.

1. *Was the Service application of the eagle fatality model for the 90 turbine wind energy project example accurate and scientifically unbiased given available data? If not please explain specific changes the Service should make in applying the eagle model to this example.*

- Reviewer 1: The data in the presentation was correct once it was run with 35 eagle minutes (rather than 36 as stated in the Webinar page 32) pre-construction phase. The numbers were also run in OpenBugs to demonstrate the slight additional variation in the number of fatalities rather than their expected value.
- Reviewer 2: The application to the 90 turbine project is appropriate given the spatial and temporal coverage, and no assumptions are violated. The addition of the 2 survey points during spring migration, the location of survey points, and covering an area with a conflict due to a potential nest site are all appropriate methods.
- Reviewer 3: None of the documentation provided suggested bias or inaccurate application of the model.
- Reviewer 4: The model is especially appropriate for a relatively small facility, where non-linear scale effects are less relevant than at a much larger facility and where cumulative impacts are more easily assessed.

2. *Are there any significant peer-reviewed scientific papers that relate to the application of the eagle model to the 90 turbine wind project example, where consideration of these papers would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers.*

- Reviewer 1: No Response.
- Reviewer 2: It may be useful to distinguish different collision probabilities for young eagles.
- Reviewer 3: Research indicates that fatalities vary by turbine location and by season; stratifying the application of the model may produce a more valid, scientific outcome.
- Reviewer 4: See previous comment about other papers.

3. *Is the modeling approach used for the 90 wind turbine project sufficiently conservative, in terms of the Service goal of maintaining stable or increasing eagle populations in this example landscape?*

- Reviewer 1: No Response.

- Reviewer 2: The modeling approach would be sufficiently conservative if daylight hours were adjusted to include twilight hours (defined as Civil Twilight by NOAA). The estimate is sufficiently conservative in that it uses a mean collision probability of 0.012. Post-construction adjustments should include scavenger removal estimates of eagle carcasses to determine annual fatalities. Sufficient spatial and temporal scales were appropriate, leading to better model outputs.

- Reviewer 3: It is difficult to say whether the model is sufficient to maintain populations of eagles without additional information on fecundity and mortality rates and an estimate of population growth or a threshold target.

- Reviewer 4: The model scales well to a relatively smaller facility such as this.

3.4 Other Review Questions and Comments

Four questions were posed by the panelists to the Service;

1) Question 22 January 2013: One of the panelists has pointed out the two model runs are based on no observed fatalities. This panelist has enquired about whether it would be possible to get a data set with fatality data.

    - Answer 24 January 2013: We do not have this type of data set at this time.

2) Question 25 January 2013: Do you have a map of known eagle nests relative to the 1000 turbine project area?

    - Answer 29 January 2013: A map of eagle nests for the 1000 wind turbine project was provided. It was based on 3 years of data on active eagle nests covering both golden and bald eagles for this project. Inactive or unoccupied golden eagle maps are also shown by decade they were originally discovered.

3) Question 28 January 2013: There is confusion relating to Slide 34, from the Webinar (the modelers were not able to recreate that data), and the panel would prefer to understand where the numbers on Slide 34 came from.

    - Answer 29 January 2013: The results presented in Slide 34 come from a different version of the model update then we ultimately decided upon and presented during the webinar. The results shown on Slide 34 were attempting to take into account observer efficiency, where observers we assumed to be able to detect 80% of killed birds. In this case, rather than a binomial distribution on the total number of fatalities (F~Bin(lambda*eta,C), we had a binomial distribution on the observed number of fatalities (F_obs~Bin(F_true,0.8), where F_true = eta * lambda * C. The model was run using Markov chain Monte Carlo in WinBUGS, not with R, or the code that was provided to the reviewers. We have people researching this question further, but

given our current lack of available data for actual eagle mortalities at wind facilities (with the related carcass detection rates) we did not feel that it is important to focus on this in the context of this model review.

4) Question 31 January 2013: The proposed ruling is considering making the take permits 30-yr permits, rather than the 5-yr permits that were described by the Service personnel during our call (Webinar). My assumption is that this would directly affect the Service's ability to re-review issued permits every 5 years to account for fatalities recorded at the project site where the permit was issued. Can the Service please clarify this point as it is very pertinent to the long-term applicability of this model?

    - Answer 31 January 2013: Given the way that the proposed rule is written, if USFWS goes forward and finalizes this rule, there would still need to be a re-evaluation and re-estimation process every 5 years of the documented mortalities vs. the predicted ones (from earlier USFWS model runs). This would be true no matter what length of time we wrote the permit for (if the rule went into effect we could then write permits for 5, 6, 8, 10, 15, or whatever number of years, up to 30 years), we just couldn't exceed the established maximum term for the permit- (which is 5 years now, but would be 30 years under the new rule). So even if in the future we wrote a permit for eagle take that was good for 30 years, every 5 years over the life of that permit, we would assess what the documented mortalities were (from post-construction monitoring). And then using this information we would make adjustments to the USFWS eagle model and the predicted mortalities estimates from the model would change accordingly. So bottomline the evaluation period (5 years) would not change, even if we started writing permits for between 5 and 30 years in the future.

4.0 Overall Summary for Each Individual Reviewer

Reviewer 1

The model needs some modifications, including: moving to R/OpenBugs programming to provide more accurate variance-to-mean ratios (as variability is currently underestimated), using individual point count exposure data and post-construction fatality data (increasing variability), moving away from a Poisson distribution assumption towards a Negative-Binomial model, and better documenting codes, examples of successful runs, and audit information.

Reviewer 2

The model created by the Service includes the best known science and data and for the most part employs valid core assumptions. However, the model's core assumptions may be violated if adequate spatial and temporal data are not used. Collision probabilities of juvenile eagles should be investigated and used in the model as there is likely differential risk among age classes. Additionally, daylight hours should be adjusted to include twilight. Data must be stratified to represent the entire site area or else the results will not be applicable to areas with a diversity of habitat types and variation in topography. All known or potential eagle territories

should be surveyed to accurately describe eagle use of the area and the model should be modified to account for differential risk experienced by successful breeders versus failed or non-breeders and by resident birds versus migrants. If nest sites are found, representative survey plots should include those nest sites as eagles regularly forage within a few km of their nest sites (possibly increasing exposure, depending on the location of the nearest turbine). Stratified random surveys should be included to incorporate habitat type, topography, avoidance areas, and to investigate non-breeding eagle use.

Widespread use of the model is limited due to the lack of adequate datasets. To lessen the use of inadequate datasets, the Service should set minimum requirements on datasets collected by project proponents applying for take permits. Additionally, the Service should consider using the model at a landscape level to investigate wind farm impacts on eagle populations (while using a conservative collision risk at 80% CI to reduce variability between wind facilities).

The Service should use the model for projects that provide pre-construction data that covers all spatial and temporal strata of a site. Determination of a statistically significant coverage of strata should be determined. It is assumed this can be calculated in some way and the existence of significant strata representation is noticeable when one compares the two example projects.

It is not clear how pre-construction eagle use of a site area is related to post-construction collision risk and fatalities in an adaptive context. Use of inadequate pre-construction data will further complicate an understanding in this relationship. Lastly, post-construction fatality survey methods should be clearly defined and adhered to.

Reviewer 3

Overall, the model is simplified but is considered to be scientifically and statistically valid considering the available data. The model can be modified and improved as more adequate datasets are obtained. The model is appropriately conservative and avoids making assumptions outside the bounds of limited input data. The emphasis on adaptive management and use of iterative Bayesian modeling was considered to be a strong point given the inherent uncertainties involved in trying to predict birds' responses to turbines and the poorly understood factors that influence collision probabilities.

One fallback is that the model does not consider landscape or regional issues; it is assumed that other models are addressing regional habitat loss and their impacts on eagle populations. Suggested modifications included modeling fatality risk as a hazard function related to the duration of eagle visits, and stratifying the application of the model over season and turbine location to account for variation in time and landscape (as research indicates that fatalities vary by these factors).

Reviewer 4

Overall this is a useful model for understanding the potential impacts that wind energy facilities may have on eagle mortalities. The model is appropriately cautious for small wind facilities and appears to be using the best available information on risk. However, more caution is recommended for large scale facilities where the impacts are much harder to predict at this

time. The Bayesian model allows for adaptive management to incorporate knowledge as it comes in.

There are a number of ways that the model could be improved to more accurately predict eagle fatalities including building in non-linear scale effects, addressing problems with other assumptions, conducting a sensitivity analysis, and extending the 'eagle day' to include sunrise and sunset. The application to the 1000 turbine project seems appropriate but could be improved by addressing the temporal inadequacy of the data and by incorporating scale effects and cumulative effects into either the model or into permitting decisions. There are fewer practical concerns about the application of the model to the smaller 90 turbine facility.

5.0 Conclusions and Recommendations

The Service has developed a Bayesian model to predict bald and golden eagle fatalities at wind energy facilities and requested an external scientific peer review to examine the model's scientific merit, assumptions, and statistical rigor. The model received positive comments from four reviewers with respect to its general applicability and was considered to be scientifically and statistically valid in its purpose of defining the relationship between eagle exposure, collision probability, and fatalities, given adequate datasets are available to feed the model. The emphasis on adaptive management and use of iterative Bayesian modeling was considered to be a strong point given the inherent uncertainties involved in trying to predict birds' responses to turbines and the poorly understood factors that influence collision probabilities.

Various limitations were discussed and suggestions were made on how the model could be improved in order to validate the model's general applicability. Some general concerns in the model's effectiveness surrounded the availability of adequate data or the ability to collect adequate data that captures variability in eagle behavior both spatial and temporally, and the ability to accurately determine the effects of fatalities on eagle populations. Some concern was also expressed regarding the use of a Poisson distribution to model eagle minutes and fatalities because the Poisson distribution likely underestimates variability and in this case, violates the assumption of independence. It was suggested that by rewriting the model in R and OpenBugs, the Poisson distribution assumptions could be relaxed to incorporate additional variation by modeling individual exposure and fatality data on a year-by-year basis rather than relying on summary data.

It was also suggested that rather than pooling the data across the site it would be more appropriate to stratify the data in biologically relevant seasons (breeding, migration, and non-breeding), topography, wind speeds, between resident and migrant eagles, and by eagle age (an investigation into age class collision probabilities was recommended). Project scale effects (i.e. number of turbines present) were not considered in the model, nor were the effects of construction and monitoring on eagle behavior. Reviewers also believed that various assumptions needed to be strengthened or clarified in order to validate the utility of the model.

APPENDIX A

Model Output Associated with
the
Peer Review of the Eagle Fatality Model
and its
Application to Wind Energy Development Projects
for the
U.S. Fish and Wildlife Service

COMBINED MODEL OUTPUT
Peer Review of the Eagle Fatality Model and its Application to Wind Energy Development Projects

February 1, 2013

Notes from Modeling Reviewer #1

80 Turbine Project

I made minor modifications to their code so that a single PDF file will be created for all the output rather than sending some output to the R console and some to a separate plot that need to be combined together. Other than that, no changes to their code and it was run "as is".

When working on the project, I noticed that the Webinar (page 32) says there were 36 Eagle-Minutes observed in this project, but the actual code (PWRC_CMData3.R file) said there were 35 Eagle-Minutes. I've updated this run so that the output now matches that shown in the Webinar on the bottom half (the adjusted value) on page 33. Please replace the previous output for this model with this new output.

1000 Turbine Project

There are two runs corresponding to using ALL of the sampled area (including the "raptor exclusion zone") and the second run using only the areas not in the exclusion zone.

Notes from Modeling Reviewer #2

Apart from modifications to file system paths and output formatting, the model was run as-is for PWRC and Thousand Turbine Project.

Re-ran the model for PWRC and Thousand Turbine Project with daylight hours changed to 4818.03.

File created on : Tue Jan 22 22:22:14 2013

Number of simulations: 100000

Updates to Exposure Prior

aPostExp	bPostExp	aPriCPr	bPriCPr
36.977654	211.881834	1.191613	176.661100

Project: PWRC
Number of turbines: 80

Hazardous area per turbine

	EMin	nCnt	CntKM2	DayLtHr
PWRC Annual	36	104	2.010619	4454.304

Exposure rate

	Mean	SD
PWRC Annual	0.175	0.0287

Annual Collision Fatalities

	Names	Mean	SD	CI50	CI80	CI90	CI95
1	PWRC Annual	2.8	2.7	2	4.4	6.3	8.1

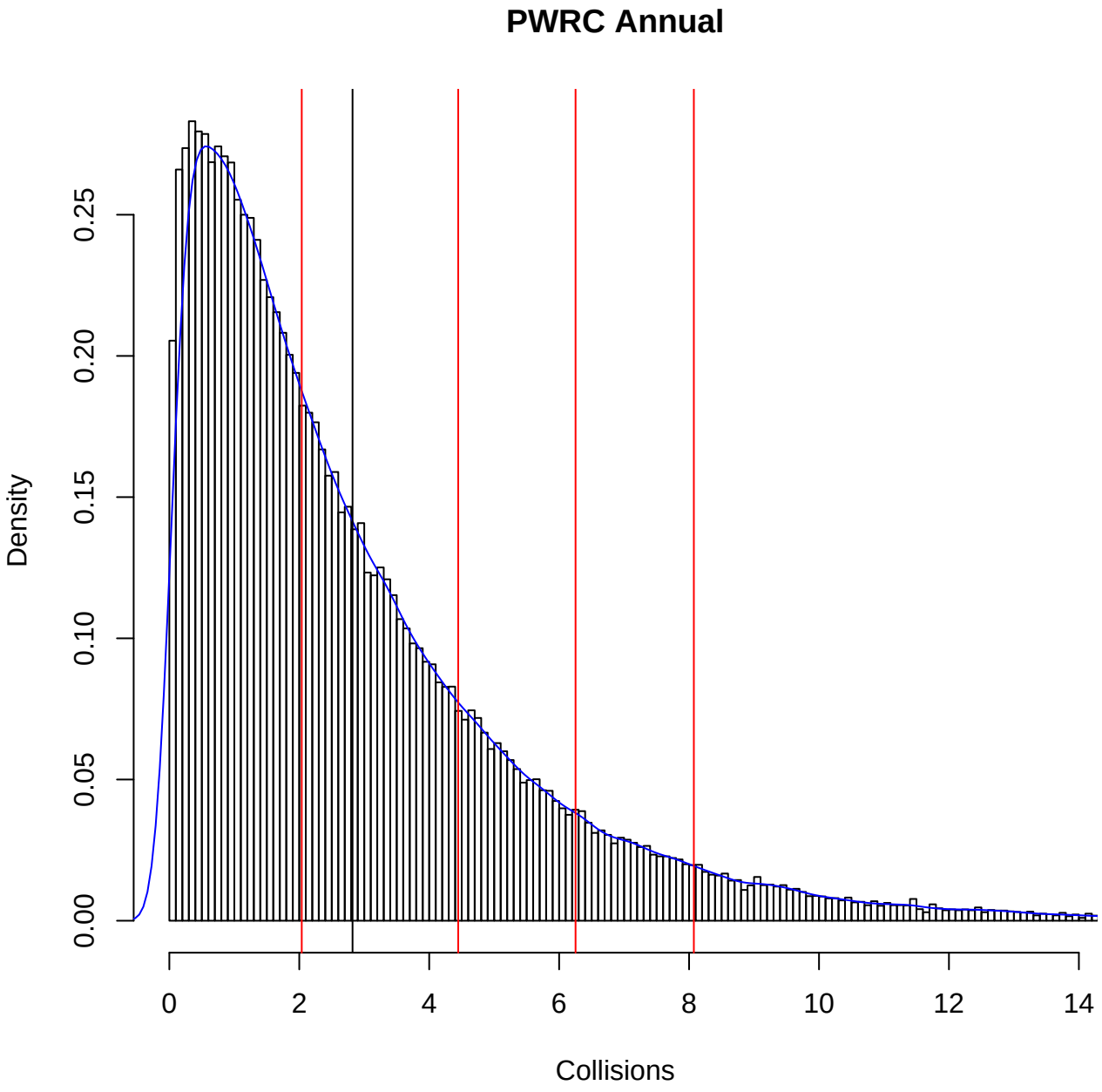

Figure A-1. Modeling Reviewer 1. 80 Turbine Output

File created on : Sun Jan 20 11:34:35 2013

Number of simulations: 100000

Updates to Exposure Prior

aPostExp	bPostExp	aPriCPr	bPriCPr
729.977654	4350.741660	1.191613	176.661100

Project: ThousandTurbineProject
Number of turbines: 1000

Hazardous area per turbine

	EMin	nCnt	CntKM2	DayLtHr
TTP	729	2162.5	2.010619	4324.26

Exposure rate

	Mean	SD
TTP	0.168	0.0062

Annual Collision Fatalities

	Names	Mean	SD	CI50	CI80	CI90	CI95
1	TTP	38	35	28	60	84	107

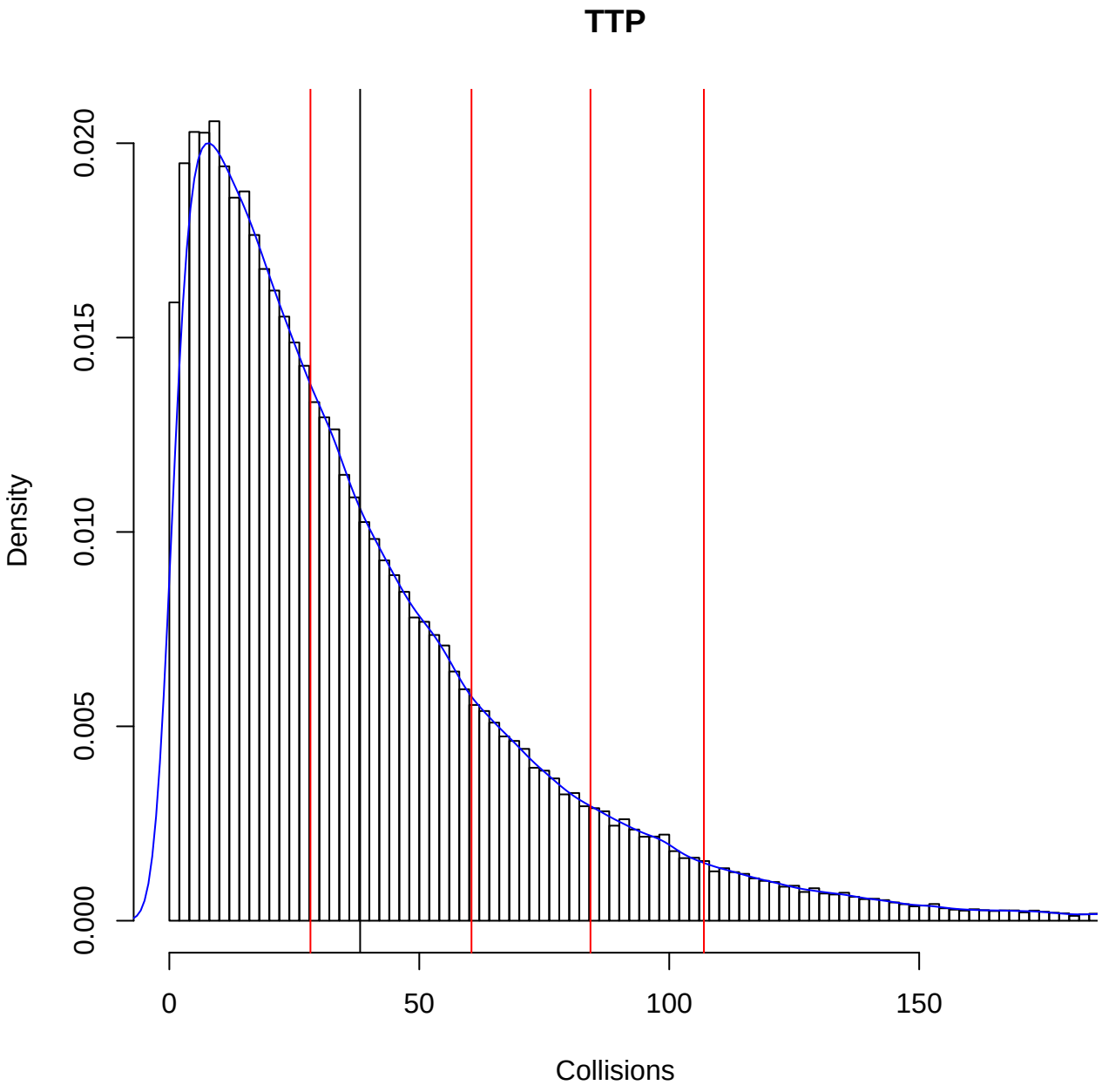

Figure A-2. Modeling Reviewer 1. 1000 Turbine Output with All Area Included.

File created on : Sun Jan 20 11:40:54 2013

Number of simulations: 100000

Updates to Exposure Prior

aPostExp	bPostExp	aPriCPr	bPriCPr
438.977654	3070.700990	1.191613	176.661100

Project: ThousandTurbineProject
Number of turbines: 1000

Hazardous area per turbine

	EMin	nCnt	CntKM2	DayLtHr
TTP	438	2162.5	1.418693	4324.26

Exposure rate

	Mean	SD
TTP	0.143	0.00683

Annual Collision Fatalities

	Names	Mean	SD	CI50	CI80	CI90	CI95
1	TTP	33	30	24	52	72	92

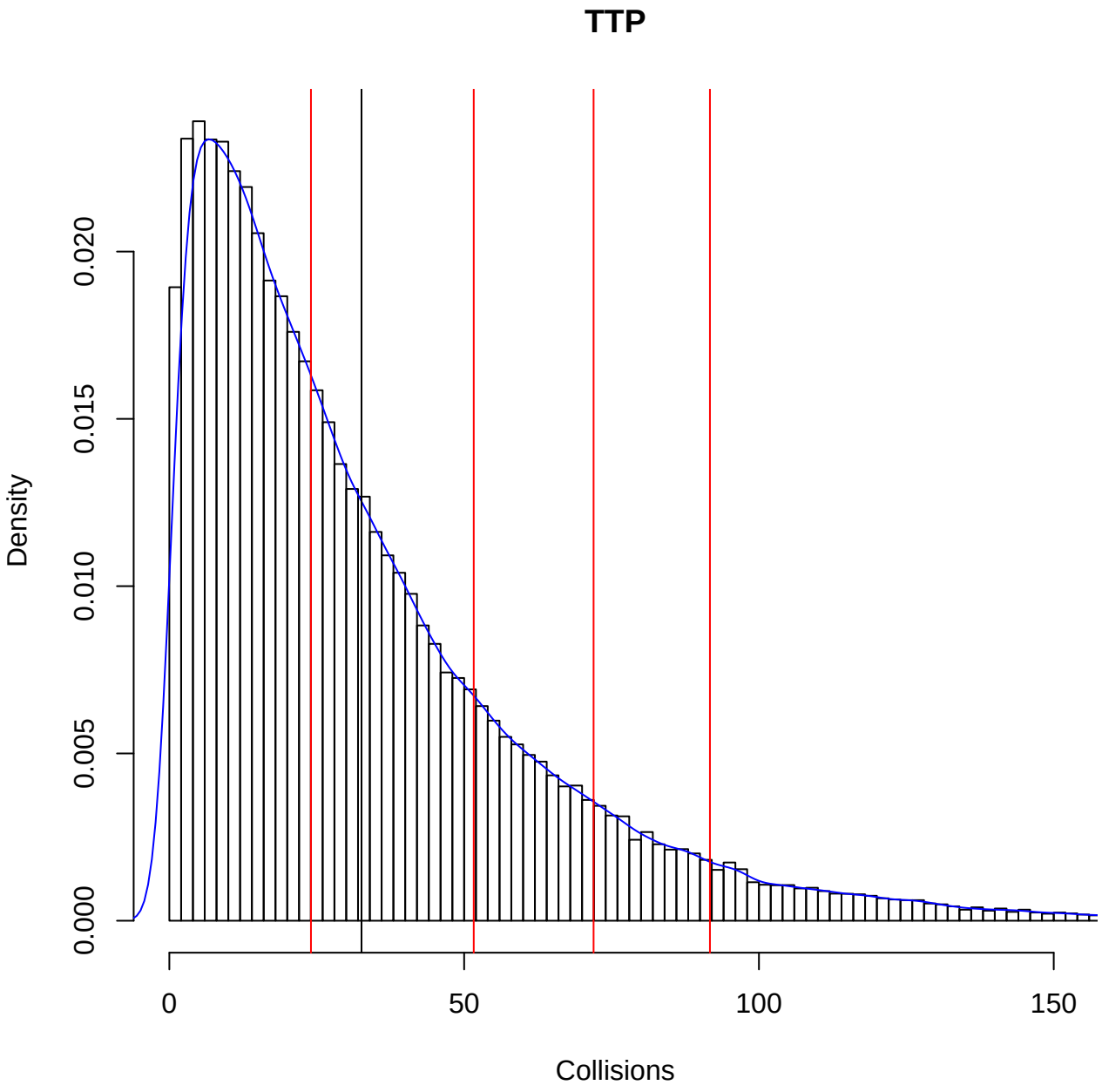

Figure A-3. Modeling Reviewer 1. 1000 Turbine Output with Reduced Area.

File created on : Mon Jan 21 16:13:41 2013

Number of simulations: 100000

Updates to Exposure Prior

aPostExp	bPostExp	aPriCPr	bPriCPr
729.977654	4350.741660	1.191613	176.661100

Project: ThousandTurbineProject
Number of turbines: 1000

Hazardous area per turbine

	EMin	nCnt	CntKM2	DayLtHr
TTP	729	2162.5	2.010619	4673.489

Exposure rate

	Mean	SD
TTP	0.168	0.00623

Annual Collision Fatalities

	Names	Mean	SD	CI50	CI80	CI90	CI95
1	TTP	41	38	31	65	91	116

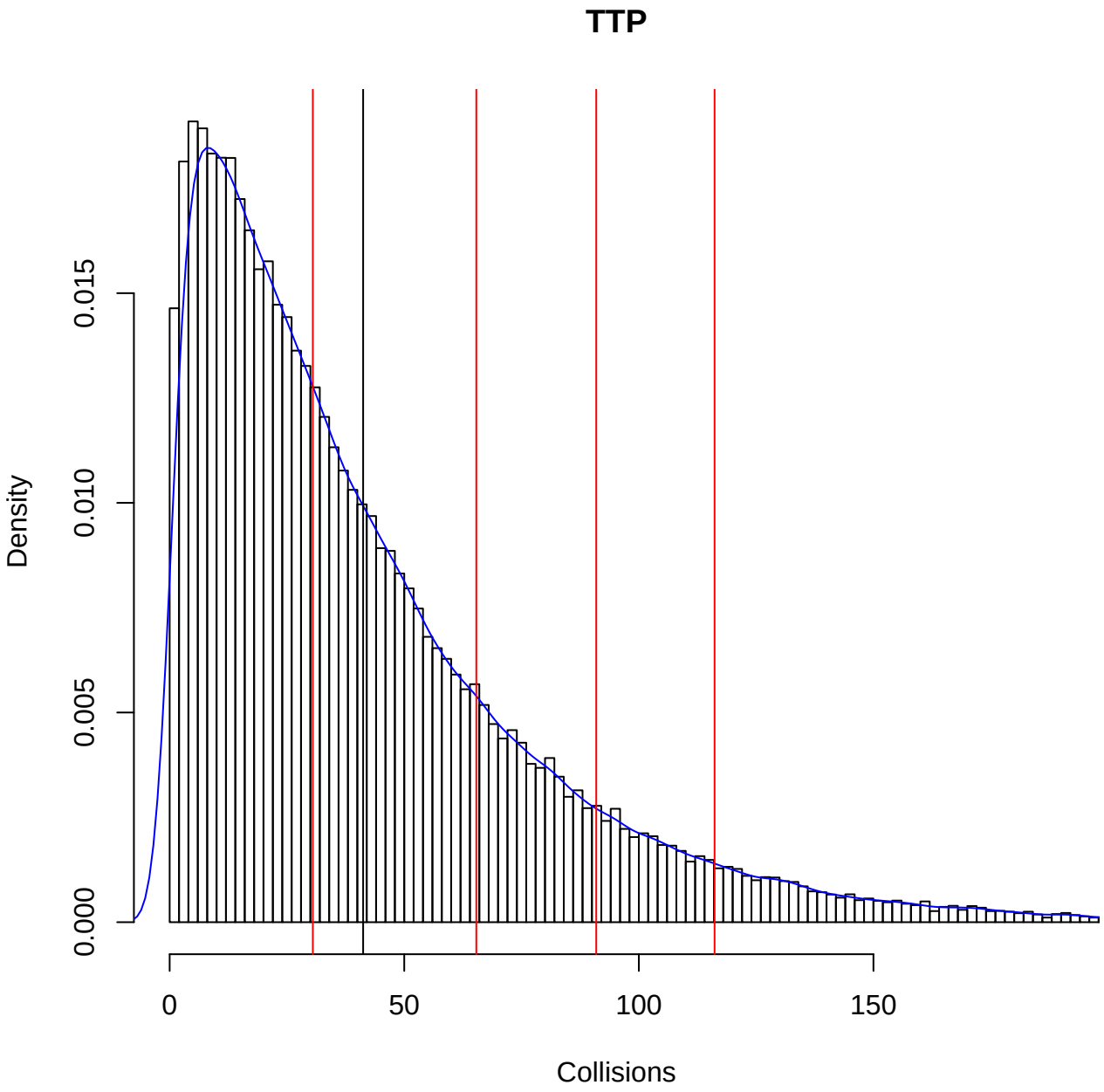

Figure A-4. Modeling Reviewer 1. 1000 Turbine Output with 4818 Daylight Hours.

```
Created:  Fri Jan 25 13:31:26 2013
Project:  ThousandTurbineProject
Turbines:  1000
Simulations:  100000

Survey
                   EMin   nCnt   CntKM2 DayLtHr
TTP with Avoidance  438 2162.5 1.418693 4324.26

Updates to Exposure Prior
   aPostExp    bPostExp     aPriCPr     bPriCPr
 438.977654 3070.700990    1.191613  176.661100

Exposure Rate
                    Mean      SD
TTP with Avoidance 0.143 0.00681

Annual Collision Fatalities
                Names Mean SD CI50 CI80 CI90 CI95
1 TTP with Avoidance   33 30   24   52   72   91
```

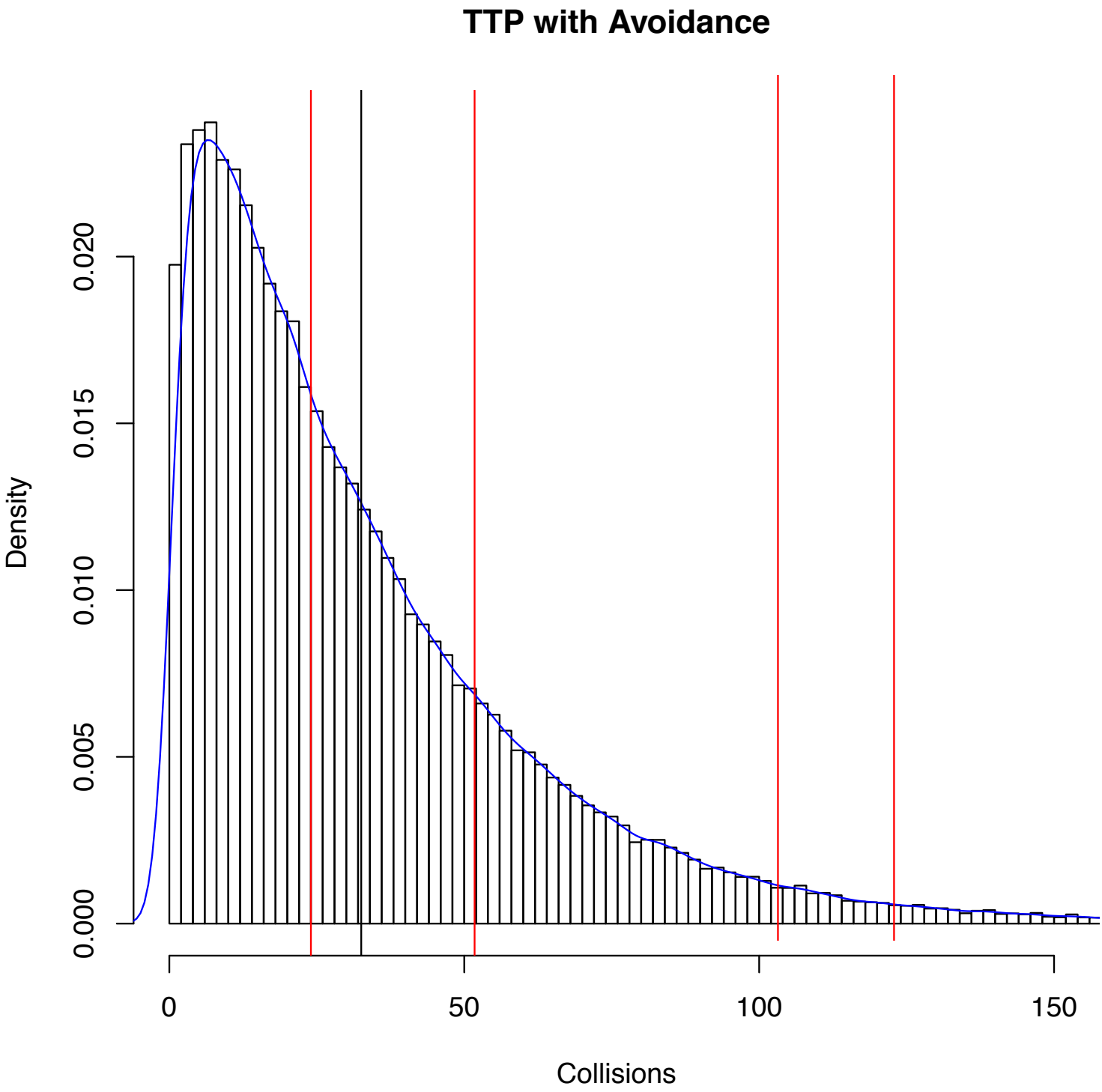

Figure A-5. Modeling Reviewer 2. 1000 Turbine Output Reduced Area.

```
Created:  Fri Jan 25 13:31:43 2013
Project:  ThousandTurbineProject
Turbines:  1000
Simulations:  100000

Survey
    EMin   nCnt   CntKM2 DayLtHr
TTP  729 2162.5 2.010619 4324.26

Updates to Exposure Prior
   aPostExp    bPostExp     aPriCPr     bPriCPr
 729.977654 4350.741660    1.191613  176.661100

Exposure Rate
     Mean      SD
TTP 0.168 0.00622

Annual Collision Fatalities
  Names Mean SD CI50 CI80 CI90 CI95
1   TTP   38 35   28   60   84  107
```

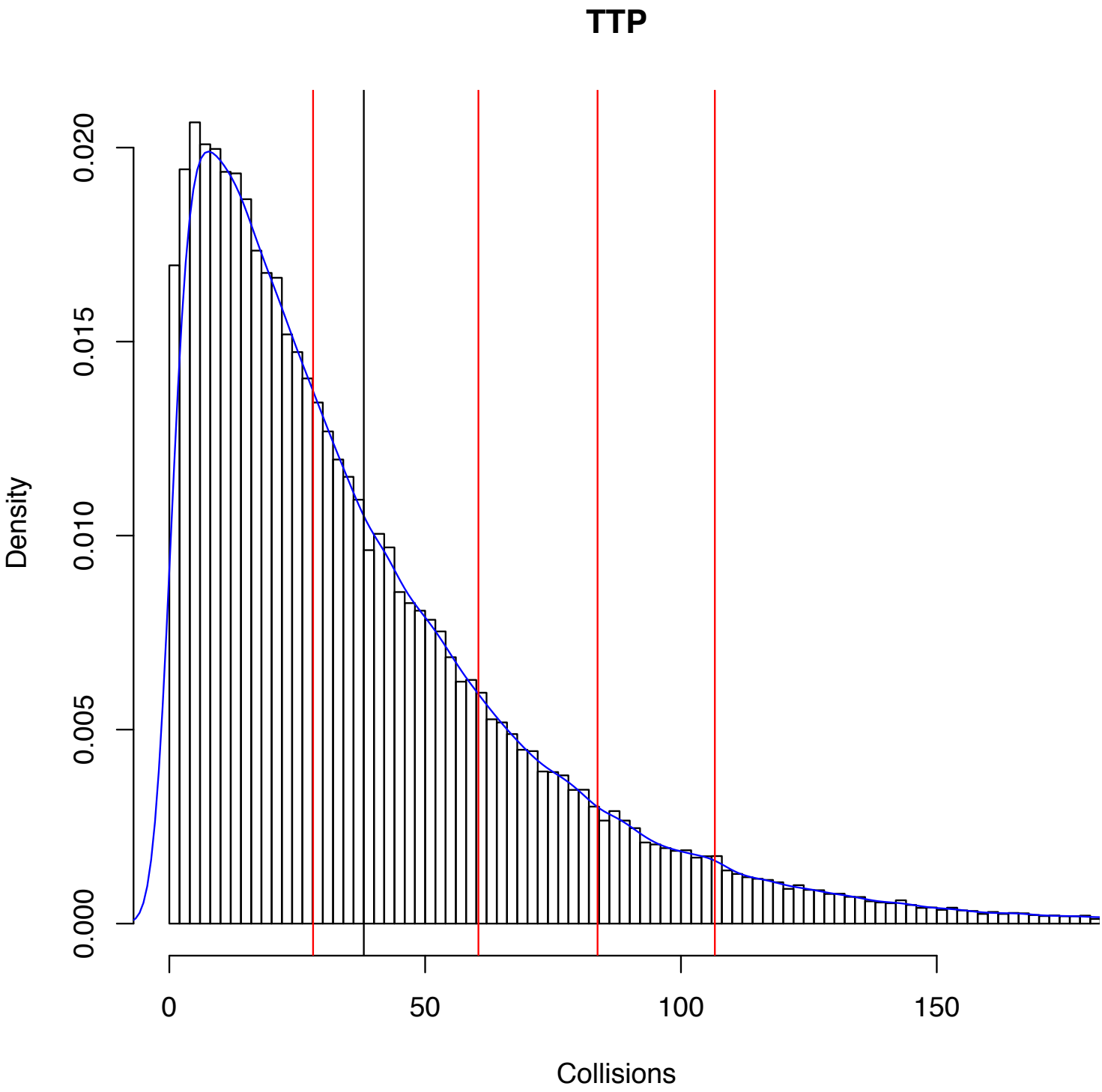

Figure A-6. Modeling Reviewer 2. 1000 Turbine Output All Area.

```
Created:  Fri Jan 25 14:40:26 2013
Project:  ThousandTurbineProject
Turbines:  1000
Simulations:  100000

Survey
                   EMin   nCnt   CntKM2  DayLtHr
TTP with Avoidance  438 2162.5 1.418693 4673.489

Updates to Exposure Prior
   aPostExp    bPostExp     aPriCPr     bPriCPr
 438.977654 3070.700990    1.191613  176.661100

Exposure Rate
                    Mean      SD
TTP with Avoidance 0.143 0.00682

Annual Collision Fatalities
                Names Mean SD CI50 CI80 CI90 CI95
1 TTP with Avoidance   35 32   26   55   77   99
```

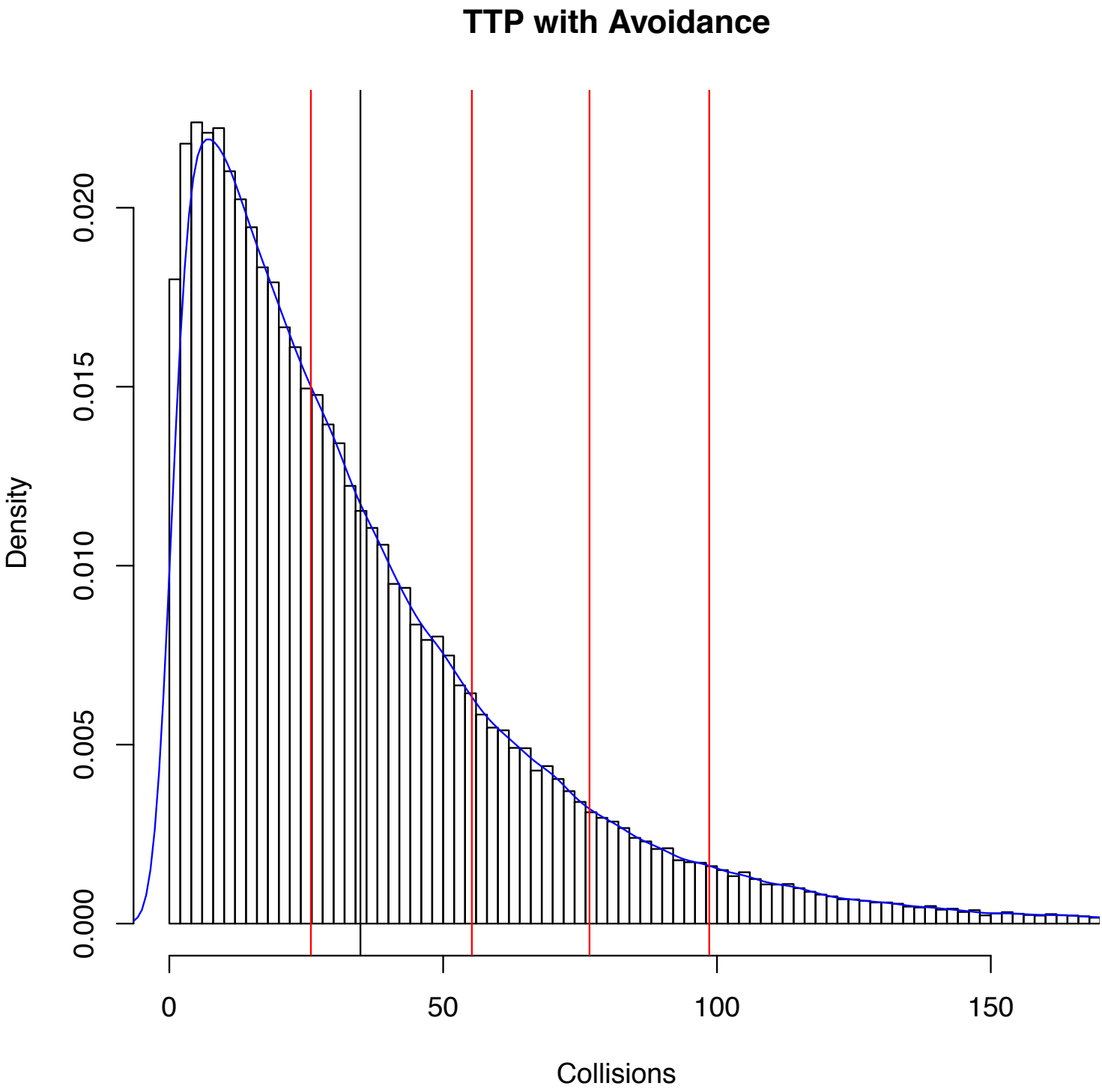

Figure A-7. Modeling Reviewer 2. 1000 Turbine Output All Area, 4818 Daylight Hours.

```
Created:  Fri Jan 25 14:40:36 2013
Project:  ThousandTurbineProject
Turbines:  1000
Simulations:  100000

Survey
    EMin   nCnt   CntKM2  DayLtHr
TTP  729 2162.5 2.010619 4673.489

Updates to Exposure Prior
   aPostExp    bPostExp     aPriCPr     bPriCPr
 729.977654 4350.741660    1.191613  176.661100

Exposure Rate
     Mean      SD
TTP 0.168 0.00622

Annual Collision Fatalities
  Names Mean SD CI50 CI80 CI90 CI95
1   TTP   41 38   31   66   91  116
```

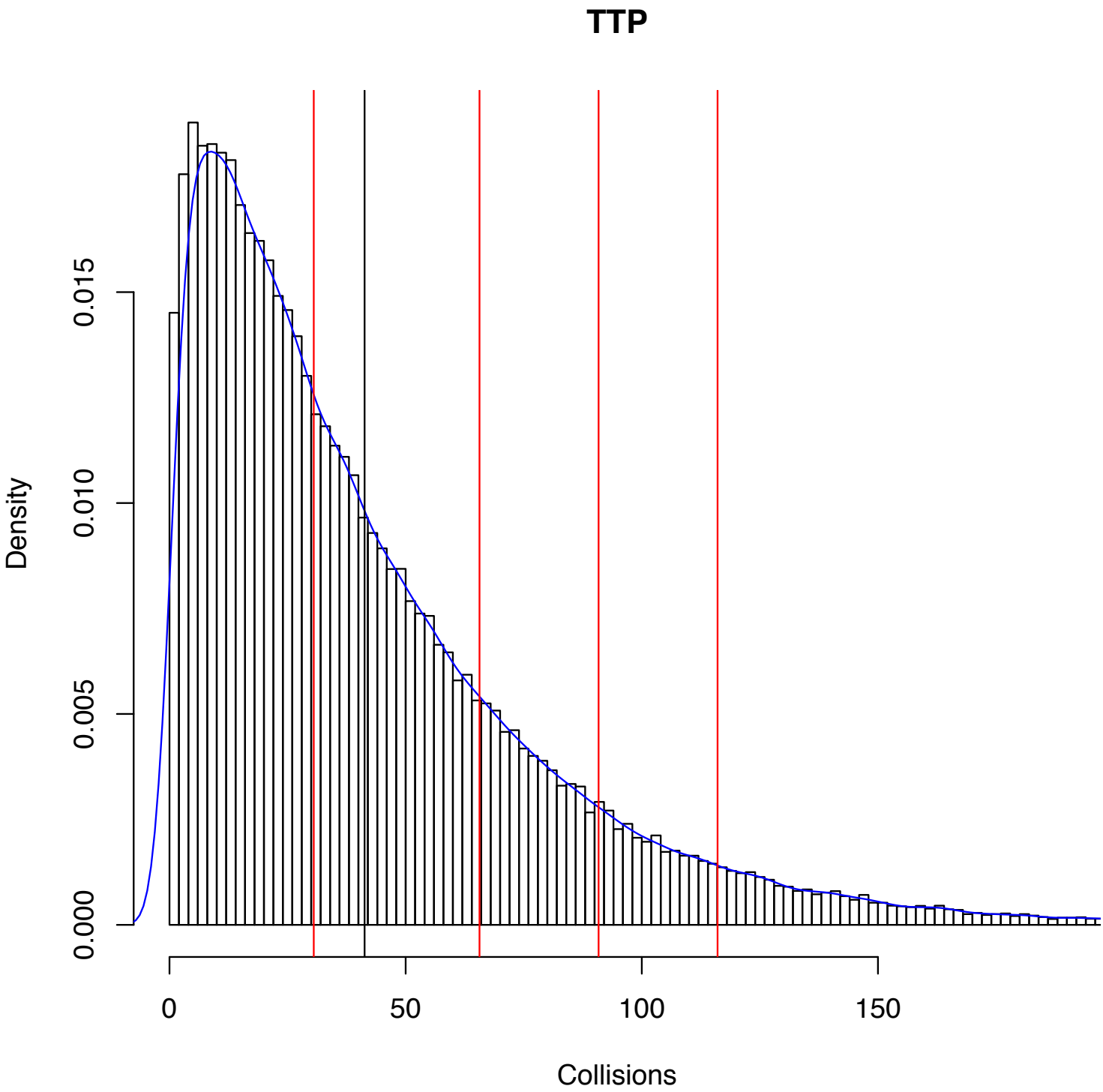

Figure A-8. Modeling Reviewer 2. 1000 Turbine Output Reduced Area, 4818 Daylight Hours.

```
Created:  Fri Jan 25 13:31:14 2013
Project:  PWRC
Turbines:  80
Simulations:  100000

Survey
            EMin nCnt   CntKM2  DayLtHr
PWRC Annual   35  104 2.010619 4454.304

Updates to Exposure Prior
  aPostExp   bPostExp    aPriCPr    bPriCPr
 35.977654 211.881834   1.191613 176.661100

Exposure Rate
            Mean     SD
PWRC Annual 0.17 0.0284

Annual Collision Fatalities
        Names Mean  SD CI50 CI80 CI90 CI95
1 PWRC Annual  2.8 2.6    2  4.4  6.1  7.9
```

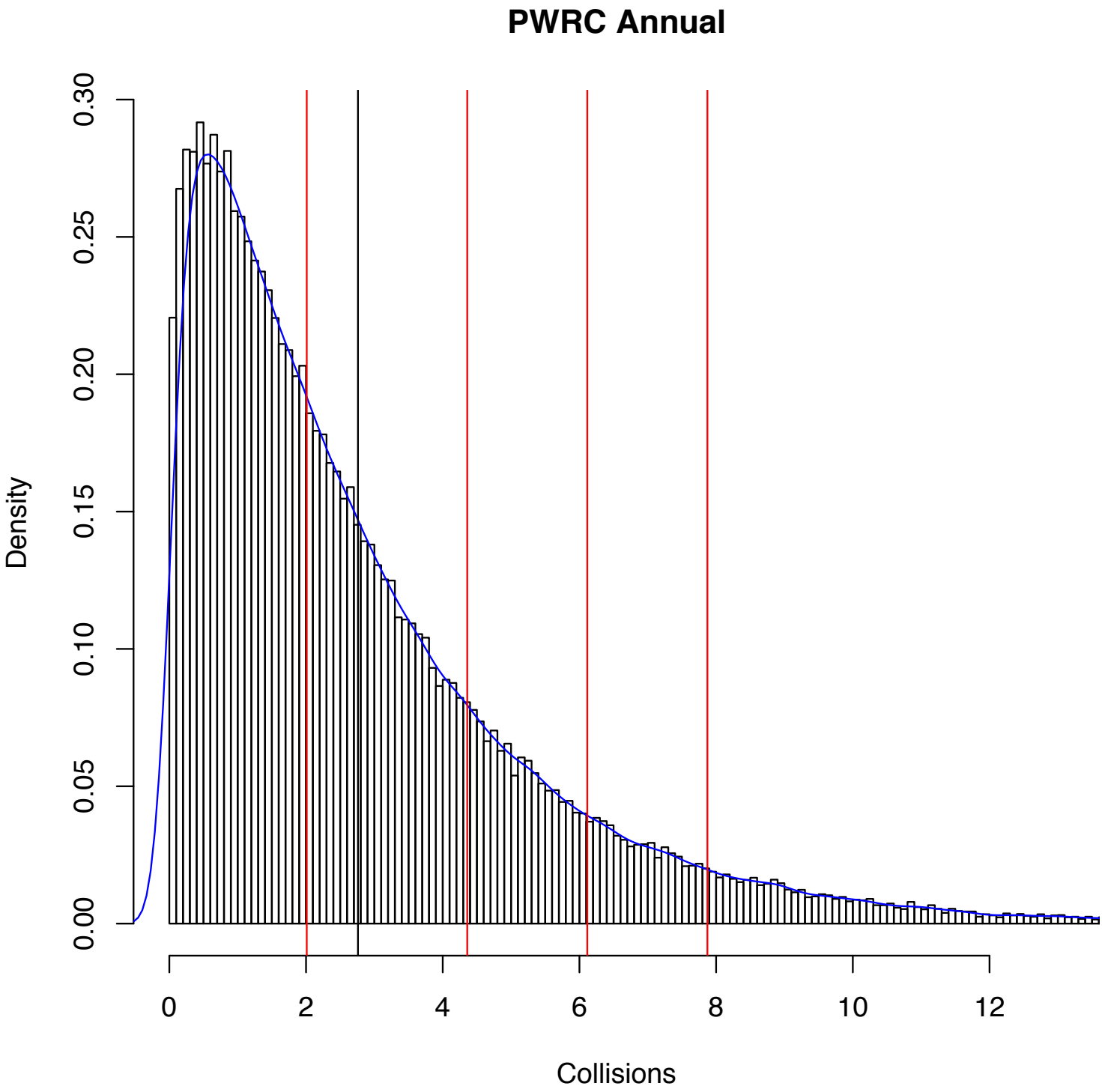

Figure A-9. Modeling Reviewer 2. 80 Turbine Output.

```
Created:  Fri Jan 25 14:40:10 2013
Project:  PWRC
Turbines:  80
Simulations:  100000

Survey
            EMin nCnt   CntKM2 DayLtHr
PWRC Annual   36  104 2.010619 4818.03

Updates to Exposure Prior
  aPostExp   bPostExp    aPriCPr    bPriCPr
 36.977654 211.881834   1.191613 176.661100

Exposure Rate
             Mean     SD
PWRC Annual 0.174 0.0287

Annual Collision Fatalities
        Names Mean  SD CI50 CI80 CI90 CI95
1 PWRC Annual  3.1 2.9  2.2  4.8  6.8  8.7
```

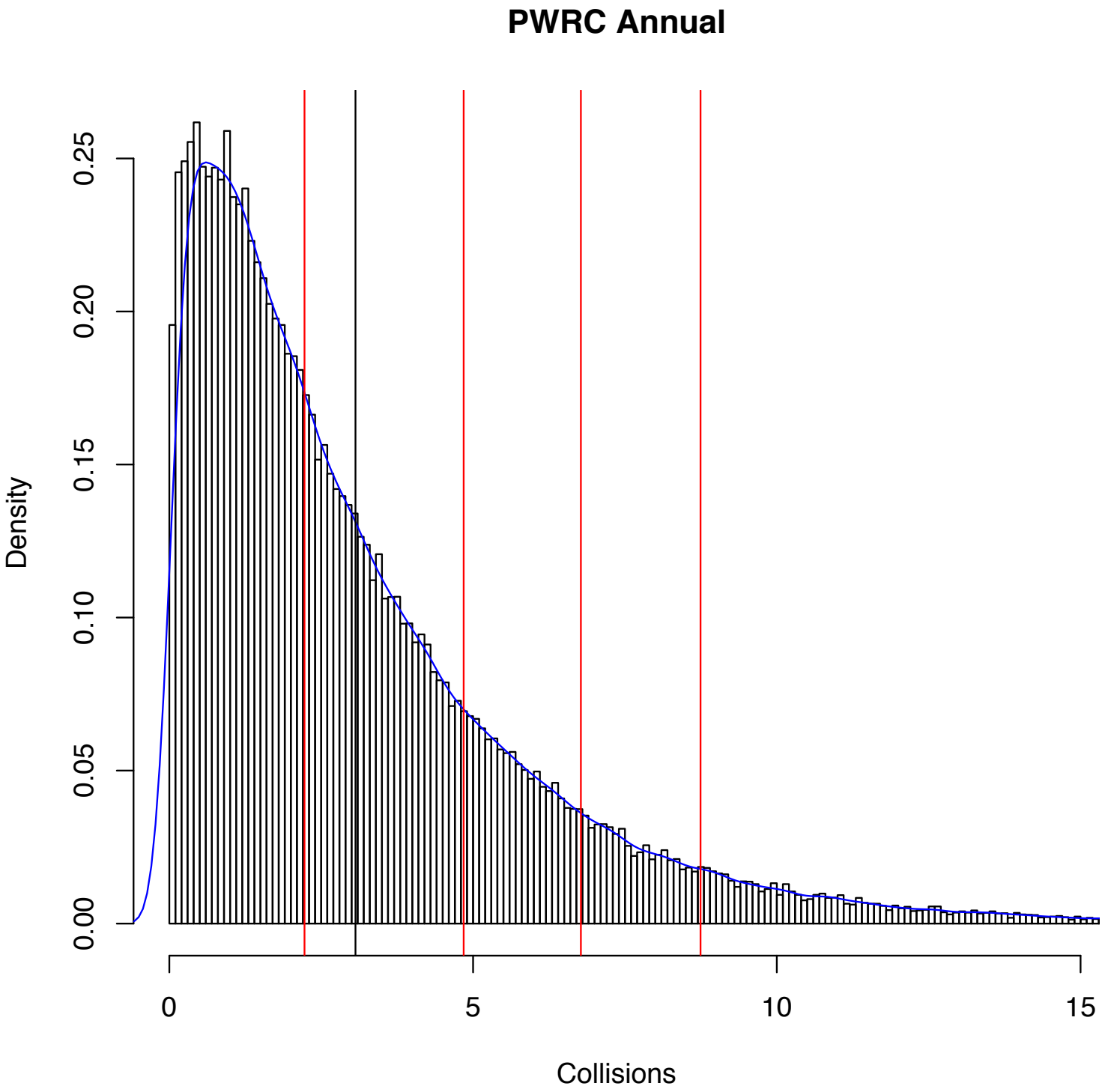

Figure A-10. Modeling Reviewer 2. 80 Turbine Output, 4818 Daylight Hours.

APPENDIX B

Complete Reviewer's Responses
for the
Peer Review of the Eagle Fatality Model
and its
Application to Wind Energy Development Projects
for the
U.S. Fish and Wildlife Service

COMMENTS FROM REVIEWER 1

January 29, 2013 (Revised 4 March 2013)

1.0 Introduction

The purpose of this review is to provide a formal, independent, external scientific peer review of the U.S. Fish and Wildlife Service (Service) eagle model for predicting fatalities at wind energy facilities in the U.S., and the application of this model to both a proposed 1000 turbine wind project and a second, smaller, more typical, wind facility example of 90 turbines.

1.1 Background

As part of the U.S. Fish and Wildlife Service (Service) Eagle Conservation Plan Guidance (ECPG), the Service developed a Bayesian model to predict the annual fatality rate for bald and golden eagles at a given wind energy facility. This Service model defines the relationship between eagle exposure, collision probability, and fatalities, while accounting for uncertainties. The Service model is intended to provide a foundation for modeling fatality predictions from eagle exposure to hazards posed by wind turbines, because the actual relationships among eagle abundance, fatalities, and their interactions with factors that influence collision probability are still poorly understood. Further, the Service model serves as a basis for learning (i.e., an adaptive framework) and should provide a conservative benchmark when exploring other candidate models that attempt to incorporate additional variables and complexity. Through an adaptive management framework, the Service intends to refine the model with updates and improvements over time.

Given both the current and future use of the Service eagle fatality model to predict both bald and golden eagle fatalities associated with proposed wind energy development projects throughout the U.S., the model and its application in predicting eagle fatalities would benefit from a formal, external, independent, scientific peer review to assess both its scientific validity and whether the Service is using it in an appropriate and unbiased manner as applied to both large and small wind energy projects. The Service desires to use the most scientifically valid and robust model in predicting eagle fatalities at wind energy facilities and to ensure the model is appropriately applied. Therefore, if the peer review demonstrates ways in which the existing model can be improved, this outcome is of great benefit to the Service.

The Service eagle model and all related documents and files, the ECPG Module 1- Land-based Wind Energy Technical Appendices (August, 2012), , and all data and files associated with the 2 specific wind energy development examples were provided solely for the purpose of a pre-dissemination peer review under applicable information quality guidelines. Until it is made public, no information from the Service eagle model review may be released by the contractor(s) without express written permission from the Service.

1.2 Peer Review Approach

The Service would like peer reviewers to review the approach and assumptions the Service used in developing the eagle fatality model. In order to meet the Service's objectives of this review, the review will address the following (1) the scientific merit, assumptions, and statistical rigor of the eagle fatality model itself, which provides the basis for annual eagle fatality predictions at individual project sites, (2) application of the model to the 1000 turbine wind energy project given available data and the juxtaposition of this project within its respective landscape, and (3) application of the model to a smaller, more typical, 90 wind turbine project example. Each reviewer must ensure that any scientific uncertainties (or data insufficiencies) are clearly identified and characterized, and the potential implications of the uncertainties for the

technical conclusions drawn are clear. Each modeling reviewer will conduct the model review independently but will later interact with all reviewers looking at eagle risk and impacts to produce the overall review. During the follow-up question phase, the Service will have the opportunity to pose questions to individual reviewers or the reviewers collectively as a team.

2.0 Peer Review Questions

The peer reviewers must consider and respond to the questions listed below, at a minimum, in their reviews. Additional comments can be added in Section 2.4.

2.1 General Model Review Questions

1. *Is the Service eagle fatality model for predicting eagle fatalities at wind energy facilities a scientifically and statistically valid approach for this intended purpose?*

The Bayesian approach is a sensible way to proceed given the large uncertainties involved in predicting responses of the birds to the turbines and how they will interact with the turbines. In 2.1.4, I outline some of the concerns I have with the implementation of the model. In particular, the use of the Poisson distribution to model EagleMinutes and Fatalities may not fully account for the variability in the process. The Poisson model implicitly assumes that all events occur independently – however bird behavior may not be independent. For example, the current model makes no distinction among EagleMinutes within the hazard zone that are generated by a few birds spending more time in the zone or many birds each spending a small amount of time in the zone. At the moment, the use of the Poisson distribution makes modeling easier because all results are essentially in closed form and can rely on the summary statistics (e.g. sum of EagleMinutes and sum of observation time). However, this ignores all information from the individual points that can be used to assess the reasonableness of the Poisson assumption - in particular the very strong assumption that the variance is equal to the mean. If this relationship is not valid then inference on, for example, the 80th percentile of the posterior will understate the true potential risk to the population.

2. *Is the Service eagle fatality model based upon the best available science? If any instances are found where the best available science was not used, please provide the specifics of each situation.*

No response

3. *Are the methods and assumptions that underlie the Service eagle model clearly stated and logical? If not, please identify the specific methods and assumptions that are unclear or illogical. Also, are these methods and assumptions based on the best available scientific information?*

In general, Appendix D needs to be strengthened in this regard. For example, the assumption of a Poisson distribution implicitly assumes the variance-mean ratio, but this implicit assumption was never clearly articulated, nor the possible consequences of its failure. Similarly, the assumption of independence of the incursions of the eagles into the pre-construction point count, and the fatalities post-construction was glossed over. Appendix D also presents the

model piece-meal – it would be helpful to have the entire model presented (e.g. in the form of a directed graph) showing the likelihood and prior components in one place.

I was unable to find a detailed description of how to incorporate observed fatalities into the model and the R code also appears to be silent.

4. *Are the model program files in R code used to calculate the Service eagle model results accurate? If not, please identify any programming errors and the specifics of each error.*

The basic model is a reasonable approximation to modeling the risk of eagle fatalities given the large uncertainties in how eagles react to turbines, operations of turbines, etc. However, several aspects of the implementation in the current model could be improved.

Adopt a clear Bayesian perspective.
While the various pieces of the model are spelled out in some detail in Appendix D, no explicit formulation of the data, the likelihood components (which extract information from the data), and the priors is provided.

The basic premise that the expected number of fatalities can be expressed as

$$\mu_{fatalities} = \varepsilon \lambda C$$

where ε is the expansion factor representing the amount of "risk" that eagles will be exposed to (hr km^2), λ exposure rate (EagleMinutes hr^{-1} km^{-2}) which generate eagle-minutes of interaction, and C the collision probability, which represents the probability than an eagle-minute of exposure generates a collision (EagleMinutes^{-1}). Note that this is the average number of collisions to be expected, but Appendix D states that the above expression is the ACTUAL number of fatalities.

There are two sources of information to provide information on λ and C.

First there are the baseline studies constructed during the pre-construction phase of the project where multiple point counts are conducted to measure the number of eagle-minutes of risk in a zone around each point count. The eagle-minutes observed is a continuous random variable, but the study authors have chosen to model these as discrete, independent events, following a Poisson distribution. Because the Poisson distribution is additive (i.e. the sum of two Poisson random variables is also a Poisson random variable), all that is needed is the (known) total survey effort (n, measured in hr km^2) and the total number of eagle minutes (EM) within the area of risk. Hence this data follows a Poisson distribution

$$EM \sim Poisson(n\lambda)$$

Second there are the fatality records after the project has started operation. Here the Service assumes that the observed fatalities are only a fraction (80%) of the actual fatalities that occurred during operation.[1] The actual fatalities are actual counts, and a Poisson distribution would seem to be a reasonable approximation. The observed fatalities are assumed to be a binomial process against the actual fatalities. Because of the Poisson assumption, both facets

[1] This feature of the model is not found in Appendix D, but was given in an email response to a query to the Service.

can be combined together, but I will keep them separate so that no changes are needed if a different distribution is assumed for the actual fatalities. Again, because of the additive nature of the Poisson distribution, only the total observed fatalities (OF) and the total operation-time-area (OTA in hr km^2) is needed. This data follows two step process: a Poisson distribution for the actual (unobserved) fatalities (AF), followed by a binomial distribution for the observed fatalities (OF):

$$AF \sim Poisson(OTA \times \lambda C)$$
$$OF \sim Binomial(AF, .80)$$

The detection rate for operational fatalities of 0.80 is assumed to be known, but should be estimated from a proper carcass survey design (e.g. using mark-recapture). Here Appendix D (page 38) differs from the above formulation. On page 38, the authors indicate that the "observation of fatalities follows a binomial distribution with rate C". However, this would imply that total EagleMinutes during the post-construction monitoring is known, which is incorrect. Only the total OTA is known, and it would be necessary to integrate over all possible EagleMinutes given the OTA. Indeed, later on Appendix D page 38, and Webinar page 14, the authors indicated that the "estimated number of exposure events (EagleMinutes) that did not results in a fatality" will be needed. The number of exposure-events is a random variable and is not known and cannot be used directly. It is not clear on slide 14 of the Webinar, what value of λ will be used to update the prior for C.

The unknown parameters in the model are λ and C. In the Bayesian paradigm, a prior distribution is placed on these unknown parameters. From Appendix D, we have

Prior $\lambda \sim Gamma(0.97, 2.76)$

Prior $C \sim Beta(1.2, 176.7)$

where the parameters of these distributions has been chosen after a wide review of the available data from many projects.

The prior distributions were chosen for convenience (the Gamma distribution is conjugate to the Poisson distribution, and the Beta distribution is conjugate to an (incorrectly) used Binomial distribution)

Now the Bayesian paradigm can be used to obtain the posterior distribution of the parameters. If there is no post-construction monitoring data available (i.e. OTA=0), then there is only one source of data that updates the λ parameter directly as shown in Appendix D, page 36. However, if post-construction data is available, this provides information about the product λC and it is NOT clear how to apportion this information between the two parameters because there are many combinations of the two parameters that give rise to the same Poisson distribution. The authors have chosen an approximate method to update C based (presumably) on the average value of λ (see page 14 of the Webinar) but I could find no discussion of this in Appendix D or other parts of the document, nor could I find where in the R code this is done.

Once the posterior distributions for the parameters are obtained, the predictive distribution for future fatalities can also be modeled as a Poisson distribution if the expected operation time-area (ETA in hr km^2) is known, i.e.

$$F \sim Poisson(ETA \times \lambda C)$$

This is NOT a likelihood component because the value of F is unknown. The ETA can be adjusted for a 1 year of 5 year planning horizon. Notice that Appendix D erroneously models

$$F = ETA \times \lambda C$$

This would model the EXPECTED number of fatalities – the future number of fatalities would have additional variation because of the distribution of the future number of fatalities around the mean.

As a side benefit, the distribution of the actual number of fatalities during the post-construction phase is also estimated, i.e. the distribution of AF based on the observed fatalities (OF) and the detection rate of 0.80.

Use OpenBugs

I suspect that there is NO closed form posterior for this (corrected) model because of the inability to separate information about λC based on the fatality data. Consequently, I would recommend that the model be rewritten in a combination of R and OpenBugs. I have attached sample code (and some output) showing how this can be relatively easily done for a single stratum study in R with an embedded call to OpenBugs. No knowledge of OpenBugs would be needed by users of this code and if the user can run R, then they can use this code directly.

The key advantage of moving to OpenBugs is that it is no longer necessary to pick simple forms (conjugate) for the priors. So, for example, it is relatively easy to relax the Poisson distribution assumptions to incorporate additional variation by modeling the individual point count data and the fatality data on a year-by-year basis.

Model Assessment

Because the model assumes Poisson distributions, only the summary data is needed to update the priors. However, there is valuable information in the detail records from both the exposure (preconstruction) study and the fatality (post-construction) study. The OpenBugs code should model the individual data rather than relying on the summary data. In particular, the Poisson distribution makes a very specific assumption about the variance-to-mean ratio but much count data is overdispersed. This will imply that credible intervals based on the Poisson distribution will be too narrow and the reported 80th percentile could be a severe underestimate of the true percentile. For example, suppose that EM_1 and EM_2 are the exposure records from point counts with n_1 and n_2 units of effort. Rather than modeling $EM=(EM_1+EM_2)$ as $EM \sim Poisson(n\lambda)$ where $n=n_1+n_2$, it would be preferable to model each component, i.e. $EM_1 \sim Poisson(n_1 l)$ and $EM_2 \sim Poisson(n_2 l)$ as the joint likelihood. While the joint likelihood is mathematically equivalent to the product of the individual likelihoods, the multiple individual records from the point counts could, for example, be used to see if the actual variance is (roughly) equal to the mean or a more dispersed distribution is needed to model the EM. Such assessments would require, for example, a Bayesian p-value where the observed distribution of the data is compared to the simulated distribution of the data. If overdispersion is detected, then it is relatively simple to change the distribution of the EM in OpenBugs to, for example, a negative-binomial distribution and no extensive reprogramming is required.

I did not find a discussion of model assessment in the documentation nor was any performed in the R-code provided.

Moving from a one-year prediction to a five year prediction.
The Webinar presentation (e.g. page 29) simply multiplies the results from a 1 year predicted distribution of fatalities by 5 for a 5-year prediction. This is correct for the mean, but incorrect for percentiles. Because the predicted number of fatalities follows a Poisson distribution, the variance to mean ratio is fixed. So if the mean increases by a factor of 5, the variance increases by a factor of 5, but the standard deviation only increases by a factor of $\sqrt{5}$ and so there will be relatively less uncertainty in the number of fatalities over longer time periods. Fortunately, the decrease in the uncertainty is relatively small, but detectable.

There is no easy way to multiply the results from a one-year forecast to get the complete results for a 5 year forecast. However, it is relatively easy to run the model twice with the ETA increased by a factor of 5.

Review of R code
(a) I found the R code extremely difficulty to follow. There is little internal documentation on what the variables mean in the code, and I often had to reverse engineer functions to figure out their arguments and what they are doing. For example, there are two functions provided to update the priors, simFatal() and simFatalFH() which appear to be identical in all respects except that there is additional argument to the function simFatalFH of EOutMin and one extra line of code where FH appears to update the prior for the collision probability but there is no documentation anywhere in the functions. Basic documentation for each function giving a list of arguments to each function and their meaning along with signposts along the way for the purpose of a block of code is needed. Even basic tenets of good programming such as a consistent indentation have not been followed.

(b) In the simFatal function, the code fragment

```
Fatalities<-ExpFac*Exp*CP
```

treats the AVERAGE number of fatalities as the actual number of fatalities. The actual number of fatalities is a random variable from a (Poisson) distribution with that mean. Fortunately, as shown elsewhere in the document, the additional variability induced by this further distribution is small if the mean is reasonably large.

(c) Functions should not print to the console. For example, the simFatal() function prints out the updated parameters of the posterior to the console without any labeling etc. All functions should return silently, and it is up to the call routine to decide if results are to be printed.

(d) A single file with the textual and graphical output should be created. This can be done using the capture.output() and textplot() functions as illustrated in the R-to-OpenBugs code returned with this review.

(e) The quantiles (and mean) on the final plot should be labeled. The Service uses the 80th percentile as a management decision point, but additional percentiles are plotted without labeling.

(f) Date and Time stamp should be added to all output for audit purposes.

(g) A version number of the code should appear on all output for audit purposes.

(h) The output should include a listing of all of the input data for purposes of auditing the results and reproducing the output as required.

(i) An R-package should be created to improve package distribution through CRAN, improve documentation of functions, provide version control, etc.

5. *How can the Service model be improved? Please identify any options to strengthen the scientific foundations of the model.*

Use the individual point count data to provide information on the variability in the EagleMinutes of exposure that is not captured by the Poisson distribution.

6. *Are there any significant peer-reviewed scientific papers that relate to the assumptions of the Service eagle model where consideration of these papers would enhance the scientific quality of the model? Please identify any such peer-reviewed papers and state specifically why incorporation of these ideas would improve the Service model.*

No response

7. *Are there any specific improvements or changes to the Service eagle model that would improve our ability to predict eagle fatalities at wind facilities? Please identify (1) what these changes would be to strengthen the scientific foundation of the model, and (2) any peer-reviewed scientific literature to support these suggested improvements or changes. In responding to this question please bear in mind that the Service does not have the latitude to require wind project proponents to collect the exact type or amount of data we would like in order to run the model, nor to specify the exact methods used to collect these data. Hence, the Service model represents a balancing act that approaches the overall issue more generally, resulting in a model that has fewer parameters than would be ideal.*

As noted earlier, the assumption of a Poisson distribution for the number of fatalities and the EagleMinutes of exposure may understate the actual variability in these measures because of the strict variance-mean relationship for the Poisson distribution. The individual point-count data and the individual yearly records should be used to verity the variance-mean relationship and to assess if this Poisson distribution is reasonable.

2.2 1000 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 1000 wind turbine project in south central Wyoming.

1. *Was the Service application of the eagle fatality model for the proposed 1000 turbine wind energy project accurate and scientifically unbiased given available data? Are the assumptions in the Service model applicable to the project and its juxtaposition within the landscape? If not please explain specific changes the Service should make in applying the eagle model.*

No response.

2. *Please assess the eagle use survey data provided to the Service by the proponents of the proposed 1000 turbine wind energy project, for use in running the eagle model to predict annual eagle fatalities at the project site. Was the eagle use survey methodology used by project proponents collected in an optimal way, both spatially and temporally, for use in*

running the eagle model? Also, was the type and quantity of data provided by proponents for this project optimal in terms of evaluating model performance?

The authors propose to adjust for the survey area by computing an "effective radius" that will, on average, cover the same area as the point counts once the avoidance areas are removed. This seems overly complicated – why not simply use the areas directly in the model rather than assuming all point counts are circular and completely covered. I think this "trick" (while arithmetically correct) has a higher chance of being done incorrectly if done in haste. This may require some slight code adjustment – rather than entering the radius, why not step back and enter area?

There appears to be sufficient data in the EagleUse worksheet in the ThousandTurbineProject.xlsx workbook to assess if the Poisson assumption is reasonable for the number of EagleMinutes – this should be done.

3. *What would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers related to eagle behavior or ecology, as they relate to model assumptions, and model application on a project of this scope.*

No response.

4. *There are other existing and proposed wind energy facilities within the same local area population of golden eagles where the proposed 1000 turbine project would be developed. The landscape in which the 1000 turbine wind project is proposed is highly rated in terms of its wind energy potential and is used by eagles for breeding, wintering, and migration. Given this backdrop, what scientific factors should the Service consider when assessing potential impacts to eagle populations?*

No response.

2.3 90 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 90 wind turbine project.

1. *Was the Service application of the eagle fatality model for the 90 turbine wind energy project example accurate and scientifically unbiased given available data? If not please explain specific changes the Service should make in applying the eagle model to this example.*

Note: When working on the project, I noticed that the Webinar (page 32) says there were 36 EagleMinutes observed in pre-construction phase of this project, but the actual code (PWRC_CMData3.R file) said there were 35 eagle minutes. I've modified thePWRC_CMData3.R file to match the webinar slide. I also modified the code to put all the output and the graphs into a single PDF file (80-turbine-output-2013-01-22.pdf).

The code did produce the output shown on page 33 of the Webinar presentation.

I also ran the OpenBugs model using the same data to demonstrate the (slight) additional variation cause by modeling the NUMBER of fatalities rather than their expected value (as was

done in the current code). [OpenBugs-80-turbine-example-2013-01-22.pdf] and relevant output presented below.

```
Estimates for one future year of turbine operations
as generated by OpenBugs code
              Mean    sd    50%    80%
C           0.0068 0.0062 0.0050 0.0106
NewFatal    2.8472 3.1712 2.0000 5.0000
NewFatal.mu 2.8539 2.7179 2.0646 4.4626
lambda      0.1743 0.0287 0.1728 0.1980
```

The statistics for the Expected number of Fatalities (NewFatal.mu) match those on page 33 of the Webinar. However, notice that when the Number of Fatalities is modeled (NewFatal) using the Poisson distribution, that now the percentiles are integers (as they must be) and there is slightly more dispersion (a wider standard deviation) than the posterior for the expected number of fatalities. In this case, there is little difference because for every time that a simulated mean (SimFatal.mu) is generated near the 80th percentile, the predicted number of fatalities will sometimes be lower than the simulated value and sometimes be higher than the simulated value, but will be roughly symmetric about the simulated value of NewFatal.mu and so the overall effect is small. The discrepancy between the two will be larger if the NewFatal.mu average is smaller so that the distribution of predicted fatalities is much more skewed, or if a distribution which is more dispersed than the Poisson (e.g. negative binomial) is used to model future fatalities.

If the same program is used to predict fatalities for the next 5 years, we get the output:

```
Estimates for FIVE future year of turbine operations
               mean     sd      50%     80%
C            0.0067  0.0061  0.0050  0.0106
NewFatal    14.1567 13.6974 10.0000 23.0000
NewFatal.mu 14.1361 13.2016 10.3610 22.2847
lambda       0.1741  0.0284  0.1724  0.1974
```

Now notice that the mean number of fatalities (NewFatal.mu) in 5 years is indeed simply 5x that mean after 1 year, but the 80th percentiles for the predicted number of fatalities after 5 years are not exactly 5x larger and (as expected) are smaller than 5x the 80th percentile of the number of fatalities after 1 year.

The Webinar (bottom half of page 34) also looks at the effect of information from finding 10 actual fatalities over the next 5 years. I was originally unable to generate the values given and they don't seem consistent with what is presented in Appendix D. However, in response to a query from this reviewer, it turns out that the information at the bottom of slide 34 is from a different formulation of the model (written in OpenBugs) where the observed fatalities have a detectability of 80% from the actual fatalities. The value of 80% is assumed to be known – in future iterations of the model, a prior could be placed on this parameter that is updated based on the results of the carcass surveys.

As noted earlier, the current implementation is incorrect because it is impossible to separate out the information from the observed number of fatalities into the λ and C parameters, but it appears that an approximation was used were the "expected" number of eagle minutes in the exposed area are used to update the prior on C.

The output from the OpenBugs program (refer to OpenBugs-Webinar-80-turbine-example-with-obs-fatalities.pdf) is presented below for comparison with the Webinar (bottom half of page 34):

```
Estimates for one future year of turbine operations
as generated by OpenBugs code with 10 observed fatalities in 5 years

                mean     sd     50%    80%
C               0.0061 0.0021  0.0059  0.0078
FatalOperating 12.5273 1.7445 12.0000 14.0000
NewFatal        2.5261 1.7637  2.0000  4.0000
NewFatal.mu     2.5259 0.7535  2.4512  3.1337
lambda          0.1740 0.0282  0.1726  0.1969
```

The posterior distribution of C has the same mean as the results on page 34 of the Webinar, but the standard deviation is quite a bit larger than that reported on page 34 of the Webinar. Without access to the USFWS OpenBugs code, I am unable to determine why, but I suspect that doing an update with a KNOWN value of λ is the cause. Recall that only the product, λC can be updated based on the observed fatalities.

My estimates of the posterior for the mean number of new fatalities per year (NewFatal.mu) has the same mean as the bottom of page 34 in the Webinar, but the sd is substantially larger. Again, I suspect the cause of this is the Service update with a known value of λ when finding the posterior of C. Again notice the difference between the posterior for the mean number of new fatalities per year (NewFatal.mu) and the number of new fatalities per year (NewFatal) which must be an integer. Also notice that the distribution of the number of new fatalities/year has a larger sd than the distribution of the average number of new fatalities/year.

Again, when the number of new fatalities is projected forward for an additional 5 years,

```
Estimates for FIVE future years of turbine operations
based on my OpenBugs code and 10 observed fatalities
in the past 5 years of operating.
                  mean   sd      50%    80%
C                0.0061 0.0021  0.0059  0.0078
NewFatal        12.6334 5.2299 12.0000 17.0000
NewFatal.mu     12.6439 3.8266 12.2516 15.6893
```

Again, note that while the mean of the posterior of the mean number of new fatalities in 5 years is 5x that for a single year, the percentiles are not 5x larger. Also notice that the posterior distribution for the number of new fatalities over the next 5 years has a substantially wider sd than the posterior for the mean number of new fatalities over the next 5 years. Again, using the mean number of new fatalities as a predictor is incorrect.

My OpenBugs code also provides an estimate of the actual number of fatalities during the operating period. Not surprisingly, the mean of the posterior is simply the 10 observed fatalities/ 0.80 (the detection rate)

Note that the R code provided did not have code to update the prior for C given observed fatalities and the information on the bottom of page 34 is based on using the Service OpenBugs code which was not provided to the review team. Consequently the causes of the difference between the results of my OpenBugs code and the results on page 34 of the Webinar is based on speculation after reading Appendix D.

2. *Are there any significant peer-reviewed scientific papers that relate to the application of the eagle model to the 90 turbine wind project example, where consideration of these papers would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers.*

No response.

3. *Is the modeling approach used for the 90 wind turbine project sufficiently conservative, in terms of the Service goal of maintaining stable or increasing eagle populations in this example landscape?*

No response.

2.4 Other Review Questions/Comments

No additional comments.

3.0 Conclusions

I recommend

- Move to R/OpenBugs program to provide more flexibility in the variance-to-mean ratio of the Poisson (e.g. move to a Negative-Binomial model) and to properly model exposure and collision data

- Use the individual point count and the year post-construction fatality data to perform model assessment.

- Better documentation of code and examples of successful runs (with output) and audit information are essential if the model is to be used successfully.

COMMENTS FROM REVIEWER 2

January 31, 2013 (Revised 7 March 2013)

1.0 Introduction

The purpose of this review is to provide a formal, independent, external scientific peer review of the U.S. Fish and Wildlife Service (Service) eagle model for predicting fatalities at wind energy facilities in the U.S., and the application of this model to both a proposed 1000 turbine wind project and a second, smaller, more typical, wind facility example of 90 turbines.

1.1 Background

As part of the U.S. Fish and Wildlife Service (Service) Eagle Conservation Plan Guidance (ECPG), the Service developed a Bayesian model to predict the annual fatality rate for bald and golden eagles at a given wind energy facility. This Service model defines the relationship between eagle exposure, collision probability, and fatalities, while accounting for uncertainties. The Service model is intended to provide a foundation for modeling fatality predictions from eagle exposure to hazards posed by wind turbines, because the actual relationships among eagle abundance, fatalities, and their interactions with factors that influence collision probability are still poorly understood. Further, the Service model serves as a basis for learning (i.e., an adaptive framework) and should provide a conservative benchmark when exploring other candidate models that attempt to incorporate additional variables and complexity. Through an adaptive management framework, the Service intends to refine the model with updates and improvements over time.

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2.0 Peer Review Questions

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2.1 General Model Review Questions

1. *Is the Service eagle fatality model for predicting eagle fatalities at wind energy facilities a scientifically and statistically valid approach for this intended purpose?*

I believe the Service eagle fatality model for predicting eagle fatalities is a scientifically valid approach for its intended purpose, given adequate data are available to feed the model and adequate strata are identified. If pre-construction eagle use data are not collected in a manner consistent with capturing the variability of eagle use across seasonal and spatial strata, then the model would not be a valid approach for estimating eagle fatalities at a wind energy facility.

The start/end dates are somewhat dependent on latitude. The seasonal strata I would suggest would be based on nesting and migration. For example, nesting season should be defined near mid Feb – Aug to capture the time periods associated with undulating flights and increased hunting efforts. Spring Migration is typically Mar-Apr and fall migration is Oct-Nov. Wintering Dec-Feb. Spatial strata should be defined by habitat type (e.g., fields, riparian, forested, cliff).

2. *Is the Service eagle fatality model based upon the best available science? If any instances are found where the best available science was not used, please provide the specifics of each situation.*

The only instance I am aware of that where the literature may deviate from the basic assumptions of the model is that there is a predictable relationship between pre-construction eagle exposure and subsequent fatalities, but the data are not clear. Walker at al. 2005 found golden eagle displacement by a windfarm, but Schmidt et al. 2003 and Johnson et al. 2000 (*in* Madders and Whitfield 2006) both found no significant displacement of eagles. In a review of relevant studies on raptors, Madders and Whitfield (2006) found that most raptors have low sensitivity to displacement by wind energy facilities. Given the ambiguity in the data for golden eagles, the Service model airs on the conservative side of estimating eagle use and the assumption is therefore valid until further evidence is published. There are several reports indicating differential risk among age classes of eagles (e.g., Smola windfarm in Norway, Hunt 1999) but I am not aware of peer-reviewed studies on the subject. However, age classification data are easy to collect during 800m point counts and these strata could be included in the model if different collision priors are found for age classes (I am assuming age data exist for the studies used in Whitfield 2009).

3. *Are the methods and assumptions that underlie the Service eagle model clearly stated and logical? If not, please identify the specific methods and assumptions that are unclear or illogical. Also, are these methods and assumptions based on the best available scientific information?*

I find that most assumptions are valid but there are a few that need further clarification. I will address each assumption from a biological perspective. The assumptions to the model structure are generally fine, but I caution against pooling the data across a project site. It would be more appropriate to stratify the data in biologically appropriate seasons and possible by age. It may be better to not use insufficient data rather than forcing the model. The core assumptions are valid but I urge the Service to investigate collision probabilities between age classes. Also, better define daylight hours to include twilight.

- *All eagle collisions with wind turbines are fatal.*
  This is a valid assumption. Even if the bird was injured, it would be removed from the effective breeding population.

- *Eagles are only at risk of colliding with turbines during daylight hours (flight in proximity to turbines does not occur during non-daylight hours). This can be specified further on a project-by-project basis where there are supporting data.*
  Daylight hours is a misleading definition, suggesting from sunrise to sunset. There is much data to indicate eagles are both actively foraging and traveling to/from foraging areas and roost sites during twilight hours. This assumption would be valid if stated as twilight and daylight hours. I have asked the other reviewers to run the 1000 turbine models with the daylight hours given and total annual daylight and twilight hours (civil twilight to civil dusk) for the Rawlins area to get a feel for the difference in risk assessment. I think it is important to point out that site-specific updates are based on the number of turbines off-line at any given time, not as an adjustment to light.
  Our data from adult breeders indicates about 72-100% of the twilight hours had movements during the breeding season. The percentage seems to drop a little during the winter months, but it's still in the realm of 50%.

- *Open population – eagles move between project site and surrounding areas, therefore the removal of an eagle does not result in a permanent change in eagle abundance.*
  It is valid to assume that project areas are not closed populations. While the timing of replacement likely differs between areas, this variability cannot be accounted for in a wide-spread model. Further, data from several studies on the breeding ecology of golden eagles suggests rapid replacement of breeding individuals (e.g., Altamont, pers obs). However, this assumption is predicated on a stable or increasing population of eagles. There are conflicting reports of population status of golden eagles (e.g., Good et al., Hoffman and Smith, Kochert and Steenhoff, Harmata et al., pers obs). It appears that this assumption is valid currently, but a significant effort must be continued to assess population status of golden eagles. The goal of this model and the USFWS is to maintain stable populations. It is likely that take permits will not be issued if the Service deems eagles populations are decreasing and this model would therefore not be used. Thus, if the model is in use, this assumption is valid.

- *Pre-construction eagle use data used to estimate eagle exposure are spatially and temporally representative of the stratum (or project if strata are not identified). Eagle exposure is eagle flight time in the project footprint per unit area per unit time.*
  This assumption is likely not valid with one year of data collection from a project proponent if there are nest sites within or directly surrounding the project site (e.g., within 5 miles) for the following reason: Eagle flight and ranging behavior will significantly change dependent on a successful or failed nest. For example, Marzluff et al. 1997, found that the size of the home range during the breeding season increased with the number of young fledged. This makes intuitive sense, in that adult eagles with young are more likely to increase their foraging rates in response to the need to feed young.

Therefore, if a project conducts surveys for one year or across years that don't encompass the variability of productivity effects on the ranging behavior of breeding eagles, both the temporal and spatial exposure of eagles can be significantly different. Further, if temporal strata (e.g., breeding, migration, and non-breeding seasons) are not adequately surveyed over the course of a year, the assumption may further not be valid for the same reasons. There are differential collision probabilities based on wind speed (e.g., Smallwood) and topography (e.g., Foote Creek data), so the data must be representative of these strata. Further, there will be a difference in exposure of migrants versus local eagles. For these reasons, adding the statement "or project if strata are not identified" may be very problematic, especially for large projects, assuming eagle exposure is constant across the entire project site and a year may not be valid. The problem here is not the model, but rather the lack of a safeguard for inadequate datasets.

Lowering the confidence interval (CI) limit to account for the uncertainty of combining strata is helpful, but there needs to be a clear minimum requirement of survey effort that corresponds to the project area size and the variability within. As a drastic example, use of the model would not be appropriate for a project that did 4 surveys over the course of the year. To this end, the wording by the Service that surveys should cover at least 30% of the project area, etc is helpful. But these types of guidelines are not incorporated because the Service cannot require it. My opinion is that even though the Service cannot require it, datasets that do not meet these minimums should not be used in this model. From my understanding, the Service is also not required to run this model for every dataset.

It is possible to account for this variability in the model outputs used and therefore reduce the constraints of this assumption, which has been done by the Service. I would suggest a sliding scale of CI threshold for projects depending on both the temporal and spatial scales of data collection. For example, if data were collected across one year in an area totaling <10% of the project area, use the 50CI and reduce it in proportion to the increase in data collection. That gives proponents incentive to gather more detailed data across a larger temporal scale. If 3-4 years of data are collected in an area >30% of the project site, they can use the 90% CI estimate, for example.

- *There is a predictable relationship between pre-construction eagle exposure and subsequent fatalities with a given amount of hazardous area around turbines. The project footprint is the minimum-convex hull that encompasses the wind-project area inclusive of the hazardous area around all turbines and any associated utility infrastructure.*

  Walker et al. 2005 found that golden eagles altered their ranging behavior following the construction of a wind facility to avoid the facility. However, several other studies have indicated that wind facilities do not affect eagle ranging behaviors (Madders and Whitfield (2006). Here the null hypothesis (same exposure) is more appropriate than the alternative since the model is designed to be a conservative approach. The Service further built in safe-guards to account for the alternate hypothesis by re-reviewing and altering estimates every 5 years based on actual fatality rates measured (assuming those fatality estimates are accurate).

- *The prior distribution Gamma (0.97,2.76) is appropriate for describing exposure rate and includes the range of possible exposure rates at potential sites.*

  N/A

- *Eagle flight minutes observed in the project footprint follow a Poisson or similar distribution. This could be modified where appropriate given the data.*
  N/A

- *Eagle exposure rate is uniform across a stratum (or project if strata are not identified).*
  Addressed above. All studies of eagle movements clearly show a relationship between eagle movements, habitat types, and season (e.g., Marzluff et al. 1997, Walker et al 2005, unpubl data). Further studies also show a difference in movement behaviors based on topography and lift conditions (Borher et al 2012). Annual home ranges will be different than breeding season home ranges for breeding eagles and wintering birds will likely use different strategies than breeders. Adequate survey design by the proponent will address this variability in exposure rates. In light of inadequate data, larger CI estimates should be used.

- *There is a predictable relationship between the hazardous area around a turbine and subsequent fatalities given an exposure rate. Hazardous area is the 2-dimensional rotor-swept area around a turbine or proposed turbine.*
  Given the exposure rate for a given hazardous area is correct, this is a valid assumption.

- *The prior collision probability Beta (1.2, 176.7) is appropriate for collision probability and includes the range of possible collision probabilities across sites and various risk scenarios.*
  N/A

- *The collision probability is uniform for all hazardous area and among turbines within a stratum (or project if strata are not identified).*
  This is a valid assumption with the possible exception of age classes.

- *The fatality rate is constant for all hazardous area within a given stratum (or project if strata are not identified).*
  This is a valid assumption with the possible exception of age classes. It may not be appropriate to pool strata for large projects.

- *The fatality rate is constant for a temporal/seasonal stratum (or all time periods if strata are not identified)*
  If exposure rates are accurate within each stratum, then this is a valid assumption.

4. *Are the model program files in R code used to calculate the Service eagle model results accurate? If not, please identify any programming errors and the specifics of each error.*

No response

5. *How can the Service model be improved? Please identify any options to strengthen the scientific foundations of the model.*

The model should mandate several strata, especially on large projects, including 1) Seasons: Breeding (mid Feb-Sept), Fall Migration (Oct-Nov), Winter (Dec-mid Feb), 2) Habitat Strata (forest, Riparian, Ag, Fields) and 3) Age The model was designed to work under a variety of conditions and with a variety of data quality to feed the model. However, the Service should be aware that datasets provided by project proponents may not be suitable to feed the model. It would be prudent for the Service to recognize the data deficiencies, rather than trying to make the model so global that it would include such datasets. Including datasets that violate the

assumptions would obviously undermine the utility of the model. For example, datasets that do not adequately cover the spatial, temporal, or age strata should not be used to estimate eagle fatalities at a wind facility.

I would recommend that the service institute a sliding scale of model output certainty to correlate with data received by the project proponent. This would provide incentive to a project proponent to gather more precise data over a larger temporal scale and provide the Service with more precise estimates of take. For example, if a proponent had three years of data covering 30% of the project site (incorporating all habitat types within the site) and all biologically meaningful seasons, the take estimate could be set at the 50% CI level. If the proponent only gathered one season with the same coverage, the take could be estimated using the 80% CI level.

I also encourage the Service to estimate different collision risks for juveniles and add an age stratum to the model for eagles. There is sufficient evidence to suggest that younger eagles are at a greater collision risk and assuming equal probability of collision between age classes would be incorrect.

6. *Are there any significant peer-reviewed scientific papers that relate to the assumptions of the Service eagle model where consideration of these papers would enhance the scientific quality of the model? Please identify any such peer-reviewed papers and state specifically why incorporation of these ideas would improve the Service model.*

Eichhorn et al. 2012 – Ecology and Society – May be a more up-to-date method of estimating collision risk. This paper builds upon the collision risk model by Whitfield and Madders by incorporating both habitat quality and nest locations; two pieces missing from the current model. This risk model has utility limited to the breeding season, but if seasonal strata are incorporated, this can strengthen the model by better assigning risk for eagles nesting in and around the project area.

7. *Are there any specific improvements or changes to the Service eagle model that would improve our ability to predict eagle fatalities at wind facilities? Please identify (1) what these changes would be to strengthen the scientific foundation of the model, and (2) any peer-reviewed scientific literature to support these suggested improvements or changes. In responding to this question please bear in mind that the Service does not have the latitude to require wind project proponents to collect the exact type or amount of data we would like in order to run the model, nor to specify the exact methods used to collect these data. Hence, the Service model represents a balancing act that approaches the overall issue more generally, resulting in a model that has fewer parameters than would be ideal.*

While the Service does not have the authority to require specific datasets, running the model with inadequate data will product inadequate results. *There should be a minimum requirement for datasets to be used in the model if a take permit is going to be issued.* While the Service does not have the legal authority to require proponents to use specific methodology, the Service does not have to issue permits to every proponent that applies for one. I am not versed in the legal issues surrounding this point, but the Service should provide tangible incentives for proponents to gather necessary pre-construction data. It may be useful for the Service to internally run the models for all wind facilities to obtain some type of overall eagle mortality rates for use in their eagle population level impact estimates, but proponents should not be issued a take permit based on model estimates using inadequate data. I would suggest the Service

adopt a minimum set of criterion for surveys to be included/used in the model. This minimum can be based on survey method suggested guidelines already published by the Service.

I am seeing two different scenarios in which this model is intended for use. First, the model is intended to be used on a site specific level to estimate eagle fatalities for issuance of a take permit to the project proponent. As stated above, the model is appropriate for this, given the data used to feed the model are accurate. If the data are lacking, that will lead to violations of the basic assumptions of the model. This model would not be valid in that situation. If the data are such that the assumptions are not violated (especially temporal and spatial risk assumptions), then the model is perfectly suited to address the needs of the Service. Second, I see this model being used across the larger context of wind development to estimate total eagle take across the US so the Service can assess population level effects. For example, the results of this model could be used to inform total eagle take and population level effects in conjunction with other studies currently underway by the Service (i.e., the West surveys). This context would be inappropriate if any of the datasets entered violate the basic assumptions of the model. It is my opinion that the model is over-simplified for this purpose. Again addressing minimum dataset requirements to be suitable for us in the model would address this issue.

2.2 1000 Turbine Project (TTP) Review Questions

Answer these questions with respect to applying the Service model to a proposed 1000 wind turbine project in south central Wyoming.

1. *Was the Service application of the eagle fatality model for the proposed 1000 turbine wind energy project accurate and scientifically unbiased given available data? Are the assumptions in the Service model applicable to the project and its juxtaposition within the landscape? If not please explain specific changes the Service should make in applying the eagle model, including its assumptions.*

Given the available data, the Service should not apply the model to the 1000 turbine project because the dataset provided violates several of the key assumptions of the model. First, the data violate the assumption that pre-construction eagle use data used to estimate eagle exposure are spatially and temporally representative of the stratum (or project if strata are not identified). The data provided are neither representative spatially or temporally within the project area. Second, the data violate the assumption that eagle exposure rate is uniform across a stratum (or project if strata are not identified). This assumption is incorrect because no strata were identified; making the default assumption that eagle exposure rate is uniform across the project area. The data gathered clearly indicate that eagle exposure rates were not uniform across the project site. I do not believe an accurate fatality estimate can be produced for this project with the data provided. I think the data are too few and don't adequately cover the strata to satisfy the assumption of uniform risk across the study area.

2. *Please assess the eagle use survey data provided to the Service by the proponents of the proposed 1000 turbine wind energy project, for use in running the eagle model to predict annual eagle fatalities at the project site. Given the size of the project footprint, is the available data sufficient to assess potential eagle impacts? If not, in your expert opinion what additional data is both spatially and temporally necessary for use in running the eagle model to best predict annual eagle fatalities? What are the scientific consequences of lacking such data in the analysis?*

There is a significant lack of data gathered from this project site.

A. There is inadequate coverage of the project site. After discounting the TTP areas, the mean radius of point counts was 672m and reduced the total survey area of the project site. Further, the survey plots do not adequately cover the project area, especially in Site A, where only three of the eight plots are entirely located in the proposed turbine polygons. It appears as if the plot locations were centered in high points above the river, drainages, ridges, and washes; where the raptor avoidance areas are located. While eagles are likely to nest within the avoidance areas, I would anticipate much of the foraging to occur in the turbine polygons. It is therefore prudent to locate survey plots within these areas to adequately survey the project area. The plots were set up as unlimited distance point counts, which would have been adequate. However, 800m radius large-bird point counts are more accurate and reliable, thus the adjustment by the Service. This reduction causes a large coverage gap that needs to be addressed to accurately assess eagle use. I would suggest a stratified random placement of survey plots that incorporate habitat type, topography and avoidance areas within both site A and B, in which all habitat types and topography are covered in a minimum of 30% to correspond with the Service recommendations. The lack of adequate coverage would likely lead to a misrepresentation of eagle use within the project area and increase uncertainty of the fatality estimates.

B. The temporal scale is inadequate. The arbitrary seasonal classifications of the survey seasons do not have any correlation to eagle biology. The temporal scale should be adjusted to reflect eagle biology to adequately cover courtship of breeders, fall and spring migrations, winter and nesting. The "Fall" survey minutes is misleading since it covers the breeding season as well as the fall migration period of eagles (beginning mid-Nov). The sum of the survey minutes (before excluding the TTP areas) is 36,077 minutes, not 50,166 as the "Fall" period would indicate. There were not enough surveys completed during the courtship period to adequately address risk during that time. Eagles in courtship regularly engage in undulating flight, which can be a very risky flight pattern when dealing with turbines. Plots were surveyed once/month during this time period. Plots were surveyed ½ as much during the spring migration period as they were during the fall migration period. This is germane due to the fact that eagles more regularly use topographic features (i.e., ridges and mountain ranges) during fall migration but utilize more varied landscape features during spring migration, such as open fields with thermals. The predictability of spring migration routes is reduced. Therefore, it is necessary to conduct more surveys during this time to capture the variability of eagle movements better. The temporal survey design is likely to underrepresent eagle use probability and thereby underestimate fatality estimates from the model.

There are no published papers correlating flight types with collision risk. Survey methodology should be such that these flights are mapped, which could then be incorporated in the model. This would be accomplished if enough surveys were conducted in Feb-March during courtship. The current draft has this listed as winter period, when fewer surveys are done. This may be fixed if the correct seasonal strata were incorporated with a suggested increase in surveys during courtship.

C. The point count coverage does not nor cannot assess use probability from the highest risk category of eagles, nesting birds, with the given survey method. There were two point counts that did encompass some of the potential home ranges of active GOEA nests (RM 3 and RM10) but both had sections removed due to the avoidance areas. In my opinion, 800m point count data should be gathered near both active nests (eggs laid) and inactive (but occupied) nest sites to encompass the variability of foraging patterns by territory holding adult eagles within and directly surrounding the project area. This would also be in line with the Service recommended guidelines. Coupling these point counts with others that covered the suite of habitat types and topography would be necessary to assess eagle use within the project area.

3. *What would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers related to eagle behavior or ecology, as they relate to model assumptions, and model application on a project of this scope.*

The project areas need better survey coverage, both spatially and temporally. The outcome of the model is only as good as the data going into it. The data are lacking (as described above) and the model output is suspect accordingly. If nest sites were found within the project area, representative survey plots should include those nest sites, as eagles regularly forage within a few km of their nest sites. Random surveys should have been included across the project area to investigate non-breeding eagle use. While the Service cannot require these specifics, any model outcome with such poor data will always be suspect and of little utility.

Given the amount of historic nests that occur within the project area, the Service should consider the recommendations by Kochert and Steenhof (2012) that nest sites should be protected for at least 30 years to account for nest re-use over time. If historic nests are taken, then should be included in the take estimate.

4. *There are other existing and proposed wind energy facilities within the same local area population of golden eagles where the proposed 1000 turbine project would be developed. The landscape in which the 1000 turbine wind project is proposed is highly rated in terms of its wind energy potential and is used by eagles for breeding, wintering, and migration. Given this backdrop, what scientific factors should the Service consider when assessing potential impacts to eagle populations?*

One of the core assumptions by the Service for this model is an open population of eagles, which is a valid assumption for golden eagles in the West. Because of this assumption (and the biology of eagles) it would be prudent that the Service look at the 1000 turbine project in conjunction with other existing and proposed wind projects within the general landscape. I believe this is a goal of the Service by making this model as inclusive as it can. Eagle migration occurs from the northern tip of Alaska to Mexico in the West and from northern Canada to Arkansas in the East, making this a landscape level issue. Data exist that have identified key migratory routes of eagles in the Rocky Mtn, Central and Eastern flyways and the service should combine all mortality estimates for these regions when looking at the migration strata. Particular for migratory routes, all wind energy sites should be considered when on the similar latitudes. If many projects exist on the same latitude across a flyway, it could effectively cause proportional increases in collision risk since the eagles would have fewer options to avoid turbines. Breeding populations are generally contiguous but can be separated out by BCRs, as has been done with population estimates and the breeding stratum can be inclusive of all projects within a BCR.

2.3 90 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 90 wind turbine project.

1. *Was the Service application of the eagle fatality model for the 90 turbine wind energy project example accurate and scientifically unbiased given available data? If not please explain specific changes the Service should make in applying the eagle model to this example.*

The application of the model to the 90 turbine project is appropriate and sound. The data feeding the model provide adequate coverage, both spatially and temporally. While it is difficult to determine what “spring” means since the raw data were not provided, I assume it

corresponds to spring migration and the pre-incubation period of eagles. Adding two surveys during this time period is an appropriate methodology. The survey points appear to cover the representative habitat types within the project boundary and also covered the potential conflict area with a known nest site. Given the spatial and temporal coverage, I do not feel that any assumptions have been violated.

2. *Are there any significant peer-reviewed scientific papers that relate to the application of the eagle model to the 90 turbine wind project example, where consideration of these papers would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers.*

Not that I am aware of. However, as described above, it may be useful to distinguish different collision probabilities for young eagles.

3. *Is the modeling approach used for the 90 wind turbine project sufficiently conservative, in terms of the Service goal of maintaining stable or increasing eagle populations in this example landscape?*

In the context of this project, the model would be sufficiently conservative in estimating eagle fatalities if the daylight hours were adjusted to include twilight (i.e, Civil Twilight, which is a specific time that is defined by NOAA. It has to do with when you can see, not when the sun crests the horizon.). I do not have a firm understanding of how Prior C is calculated but know it is based on Whitfield (2009). The mean collision probability used for the Service models is 0.0067. Whitfield (2009) clearly suggested using a collision risk of 0.01 for golden eagles. The Service used the 80% CI to estimate eagle fatalities at this site, which corresponded to a collision probability of 0.012; therefore the estimate is sufficiently conservative. Post-construction adjustments need to incorporate scavenger removal estimates of eagle carcasses to determine annual fatalities. Here, the Service could have incorporated a lower CI threshold level for the project proponent due to the quality of the data provided to the Service. While only one year of data was gathered, the spatial and temporal scale was appropriate, leading to better model outputs. As found by the post-construction fatalities, a 60%-70% CI threshold would have been appropriate and sufficiently conservative.

2.4 Other Review Questions/Comments

No additional comments

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3.0 Conclusions and Recommendations

The Service has created a model for estimating eagle fatalities at wind energy facilities that is grounded in sound science and based on the best available data. The core assumptions of the model are valid, but I suggest further investigating different collision probabilities of juvenile eagles or making sure that the collision probability used is that of juvenile eagles to provide a conservative mortality estimate. I suggest altering models and verbiage to include the time period from civil twilight to civil dusk as “daylight hours.” The model structure assumptions may be violated if the spatial scale of data collected by the project proponent is inadequate. This is particularly true for large wind projects that include many distinct habitat types. If data collected are not representative of the overall project area, the exposure will not be constant across the project site. Also, nesting sites of eagles should be represented in the eagle use data gathered. An important point to note is that both active nesting and occupied, inactive nesting territories

should be surveyed to accurately describe eagle use of the area. Data that include only use estimates from areas that include historically active nests will likely underestimate use during the breeding season.

The major potential issue with widespread applicability of this model is that many of the datasets used to feed the model could be inadequate, leading to inaccurate estimates of eagle fatalities. It is unfortunate that the Service does not have the regulatory authority to require specifics on data collection, but I suggest the Service use incentives to help ensure quality data. I suggest the Service can use a sliding scale CI threshold of collision probabilities to provide this incentive. Model outputs will be more accurate with higher quality data [e.g., multiple years, good spatial coverage (>30%), and representative nest site eagle minute data]. This suggestion relates to the distribution of take permits for project proponents. The Service must also use this data on a landscape level to help determine cumulative eagle take across all wind facilities. This goal is to provide a conservative estimate of eagle population level losses. It is my opinion that this model could be used for this purpose and is the best available option for this goal. Because of data uncertainty, the conservative collision risk at 80% CI should be used. By using this threshold, the variability between wind facilities is likely to be encompassed.

I recommend that the Service uses this model for projects that provide pre-construction monitoring data that do not violate the basic spatial and temporal assumptions of the model. While the specifics of what datasets do and do not violate those assumptions can be problematic, I would assume that a statistically significant coverage of strata within a project site can be determined. This point can be illustrated by the examples provided by the Service for this review. The 90 Turbine project assessed eagle use from point counts that covered all habitat types for the project area (assessed visually from the aerial photographs) and eagle nests within the project area. The use estimates were determined from data collected during a year in which the eagle nest was active and therefore a year with high eagle use (when compared to a year in which the nest was inactive). The data provided on the 1000 turbine project are such that we do not know if there is coverage of all habitat types, but it would appear that there was not representative coverage of each stratum for statistical significance.

Finally, there is a significant lack of understanding on how pre-construction eagle use relates to post-construction collision risk and fatalities. While the null dictates the model assumption is a direct correlation, the adaptive context of this model should focus on this assumption in the future. If eagle movements change due to the windmills (as suggested in the literature), then it would be good to monitor risk after the turbines are up. Using inadequate pre-construction datasets will only further complicate understanding of this relationship. Similarly, post-construction fatality survey methodology should be clearly defined and adhered to.

COMMENTS FROM REVIEWER 3

February 1, 2013 (Revised 6 March 2013)

1.0 Introduction

The purpose of this review is to provide a formal, independent, external scientific peer review of the U.S. Fish and Wildlife Service (Service) eagle model for predicting fatalities at wind energy facilities in the U.S., and the application of this model to both a proposed 1000 turbine wind project and a second, smaller, more typical, wind facility example of 90 turbines.

1.1 Background

As part of the U.S. Fish and Wildlife Service (Service) Eagle Conservation Plan Guidance (ECPG), the Service developed a Bayesian model to predict the annual fatality rate for bald and golden eagles at a given wind energy facility. This Service model defines the relationship between eagle exposure, collision probability, and fatalities, while accounting for uncertainties. The Service model is intended to provide a foundation for modeling fatality predictions from eagle exposure to hazards posed by wind turbines, because the actual relationships among eagle abundance, fatalities, and their interactions with factors that influence collision probability are still poorly understood. Further, the Service model serves as a basis for learning (i.e., an adaptive framework) and should provide a conservative benchmark when exploring other candidate models that attempt to incorporate additional variables and complexity. Through an adaptive management framework, the Service intends to refine the model with updates and improvements over time.

Given both the current and future use of the Service eagle fatality model to predict both bald and golden eagle fatalities associated with proposed wind energy development projects throughout the U.S., the model and its application in predicting eagle fatalities would benefit from a formal, external, independent, scientific peer review to assess both its scientific validity and whether the Service is using it in an appropriate and unbiased manner as applied to both large and small wind energy projects. The Service desires to use the most scientifically valid and robust model in predicting eagle fatalities at wind energy facilities and to ensure the model is appropriately applied. Therefore, if the peer review demonstrates ways in which the existing model can be improved, this outcome is of great benefit to the Service.

The Service eagle model and all related documents and files, the ECPG Module 1- Land-based Wind Energy Technical Appendices (August, 2012), , and all data and files associated with the 2 specific wind energy development examples were provided solely for the purpose of a pre-dissemination peer review under applicable information quality guidelines. Until it is made public, no information from the Service eagle model review may be released by the contractor(s) without express written permission from the Service.

1.2 Peer Review Approach

The Service would like peer reviewers to review the approach and assumptions the Service used in developing the eagle fatality model. In order to meet the Service's objectives of this review, the review will address the following (1) the scientific merit, assumptions, and statistical rigor of the eagle fatality model itself, which provides the basis for annual eagle fatality predictions at individual project sites, (2) application of the model to the 1000 turbine wind energy project given available data and the juxtaposition of this project within its respective landscape, and (3) application of the model to a smaller, more typical, 90 wind turbine project example. Each reviewer must ensure that any scientific uncertainties (or data insufficiencies) are clearly identified and characterized, and the potential implications of the uncertainties for the

technical conclusions drawn are clear. Each modeling reviewer will conduct the model review independently but will later interact with all reviewers looking at eagle risk and impacts to produce the overall review. During the follow-up question phase, the Service will have the opportunity to pose questions to individual reviewers or the reviewers collectively as a team.

2.0 Peer Review Questions

The peer reviewers must consider and respond to the questions listed below, at a minimum, in their reviews. Additional comments can be added in Section 2.4.

2.1 General Model Review Questions

1. *Is the Service eagle fatality model for predicting eagle fatalities at wind energy facilities a scientifically and statistically valid approach for this intended purpose?*

Given the goal of predicting fatalities, and the inherent limitations of the available data, I find the model scientifically and statistically valid. The emphasis on adaptive management and its realization through iterative Bayesian modeling is a strong point.

2. *Is the Service eagle fatality model based upon the best available science? If any instances are found where the best available science was not used, please provide the specifics of each situation.*

I believe the model adequately captures what can be predicted given the state of the science. The model is quite conservative in that it avoids making assumptions outside the bounds of limited input data.

3. *Are the methods and assumptions that underlie the Service eagle model clearly stated and logical? If not, please identify the specific methods and assumptions that are unclear or illogical. Also, are these methods and assumptions based on the best available scientific information?*

The assumptions are clearly stated and logical. The assumption that eagle minutes follow a Poisson distribution is perhaps the least logical, but alternative formulations are suggested in the documentation.

4. *Are the model program files in R code used to calculate the Service eagle model results accurate? If not, please identify any programming errors and the specifics of each error.*

We have reviewed the model code in detail and do not find any programming errors.

5. *How can the Service model be improved? Please identify any options to strengthen the scientific foundations of the model.*

A possible modification would be to model both the distribution of waiting times between individual entry events (entering the project or strata) and the distribution of transit times (how long each individual stays in the project or strata). This information might be retrieved from the observation of eagle minutes. Fatality risk could then be modeled as a hazard function related to the duration of the visit. If the renewal rate is very low, but duration of visits is high, then fatalities will be sensitive to the renewal rate. The hazard rate will be more important if durations are short and renewal rapid. The current model is essentially a limiting bound of this more

general model. I emphasize “possible” because although I think my suggestion could lead to a “better” model,that will depend crucially on the quantity and quality of data available. There is no point in developing it if you can’t get a sensible result out. My thought was along the lines of p(m) = p(m | t) p(t | i) p(i) where p(m) is probability of mortality, p(m|t) is probability of mortality given visit of duration t, p(t| i) is the probability of visit of duration t given an incursion, and p(i) is the probability of incursion. Some of these may of course involve additional unlisted parameters.

6. *Are there any significant peer-reviewed scientific papers that relate to the assumptions of the Service eagle model where consideration of these papers would enhance the scientific quality of the model? Please identify any such peer-reviewed papers and state specifically why incorporation of these ideas would improve the Service model.*

The report of Lucas et al. (2012) indicates that collision risk is highly heterogeneous between turbines because of their location in the landscape and relative to movement pathways. Their study is of Griffon Vultures, not eagles, but the idea is worth consideration. Implementation would require a model that links turbine placement to collision risk. This may not be feasible given the available data, but would definitely improve the modeling. It is not clear however that conclusions of Lucas et al. are directly transferable between species.

7. *Are there any specific improvements or changes to the Service eagle model that would improve our ability to predict eagle fatalities at wind facilities? Please identify (1) what these changes would be to strengthen the scientific foundation of the model, and (2) any peer-reviewed scientific literature to support these suggested improvements or changes. In responding to this question please bear in mind that the Service does not have the latitude to require wind project proponents to collect the exact type or amount of data we would like in order to run the model, nor to specify the exact methods used to collect these data. Hence, the Service model represents a balancing act that approaches the overall issue more generally, resulting in a model that has fewer parameters than would be ideal.*

Given that we lack exact models of the phenomenon, the scientific foundation will only improve through the acquisition of new data. Nonetheless, I will make a few comments.

Turbines do not present equivalent risk. Lucas et al. (2012) for example found large variation in Griffon Vulture fatalities among towers within a single installation. Drewitt and Langston (2008 and references therein) highlight how tower placement in the landscape can influence fatality rate, including eagles. It is not clear that there is sufficient knowledge to generate specific rules. It would improve the model however if it were possible to assign different risk to different turbines based on their position and context in the landscape.

The other issue that appears to have been neglected is the importance of short-duration but high-risk events. If recording of eagle-minutes only occurs during good weather, then it may not representative of what happens during storms or other high-wind events. It may be the case the bulk of fatalities occur under specialized conditions, or combinations of conditions, like high wind and low visibility. Newton (2007) cataloged numerous mass mortality events for migrating birds, although not specifically for wind farm fatalities. Other reports suggest that low visibility conditions are not an issue (Whitfield 2009 and references therein). Nonetheless, this could be an important source of temporal variation in risk not currently represented in the model.

My comment is largely about temporal variation in risk. If eagles do not fly during inclement weather and reduce their risk during these periods, that would also influence the outcome. Again, to the extent this is captured in the prior, the model is sufficient. It is unlikely that there would be a sufficient concentration of eagles to produce a mass mortality event (100’s or 1000’s

of individuals) in any single area. I suppose one might encounter very rarely a “perfect storm” that created high risk over a very large area involving a large number of birds eg a regional weather disturbance during migration. Prior results are likely to include periods of bad weather, so this issue is to some extent already dealt with in the model through the specification of the collision prior.

Although clearly infeasible given the current framework, an ideal approach would be to use telemetry or other means to gather a large number of eagle movement paths through existing projects (Nygård and Bevanger 2010). This would shed light on collision risk relative to exposure.

2.2 1000 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 1000 wind turbine project in south central Wyoming.

1. *Was the Service application of the eagle fatality model for the proposed 1000 turbine wind energy project accurate and scientifically unbiased given available data? Are the assumptions in the Service model applicable to the project and its juxtaposition within the landscape? If not please explain specific changes the Service should make in applying the eagle model, including its assumptions.*

The model was applied accurately and without apparent bias. I have little information about the larger landscape context of this project. Within the map provided, the assumptions of the model are applicable.

2. *Please assess the eagle use survey data provided to the Service by the proponents of the proposed 1000 turbine wind energy project, for use in running the eagle model to predict annual eagle fatalities at the project site. Was the eagle use survey methodology used by project proponents collected in an optimal way, both spatially and temporally, for use in running the eagle model? Also, was the type and quantity of data provided by proponents for this project optimal in terms of evaluating model performance?*

The only issue I see is there is a lack of sampling near the northern boundary of site B. Adding 2-3 surveys in this area would give a better coverage and more accurate estimate of total eagle minutes. The scientific consequence is an increase in uncertainty in posterior estimates.

3. *What would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers related to eagle behavior or ecology, as they relate to model.*

The outcome will be improved by embedding decisions about this project in the larger encompassing landscape. Fargione et al. (2012) show for example how one can use GIS and a landscape/regional approach to tradeoff wind power generation with exposure risk. These studies can also be highly data limited for individual species, but still can provide vital information about larger scale land use tradeoffs.

4. *There are other existing and proposed wind energy facilities within the same local area population of golden eagles where the proposed 1000 turbine project would be developed. The landscape in which the 1000 turbine wind project is proposed is highly rated in terms of its wind energy potential and is used by eagles for breeding, wintering, and migration. Given*

this backdrop, what scientific factors should the Service consider when assessing potential impacts to eagle populations?

Landscape-scale risk assessment should consider the regional pattern of natural land cover and anthropogenic land uses. The eagle population could be compromised by multiple individual factors, none of which alone is judges a significant detriment. Better knowledge of eagle habitat use and movement patterns would greatly improve the basis for decision making in the area.

2.3 90 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 90 wind turbine project.

1. *Was the Service application of the eagle fatality model for the 90 turbine wind energy project example accurate and scientifically unbiased given available data? If not please explain specific changes the Service should make in applying the eagle model to this example.*

None of the documentation provided suggested bias or inaccurate application of the model.

2. *Are there any significant peer-reviewed scientific papers that relate to the application of the eagle model to the 90 turbine wind project example, where consideration of these papers would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers.*

The paper by Barrios and Rodríguez (2004) indicates for soaring species fatalities vary considerably by season and turbine location. If data support stratifying the application of the model, that would improve the scientific outcome as it would account for variation through time and variation stemming from landscape context.

3. *Is the modeling approach used for the 90 wind turbine project sufficiently conservative, in terms of the Service goal of maintaining stable or increasing eagle populations in this example landscape?*

Any statement about population conservation would require additional information regarding fecundity and mortality over a sufficiently large scale to be relevant to the population. Without an estimate of population growth rate and a threshold target, it is difficult to state whether the model is sufficient to ensure maintenance of the population.

2.4 Other Review Questions/Comments

No additional comments.

3.0 Conclusions and Recommendations

The model focuses on predicting fatalities. It is dramatically simplified, but this is justified by the data available. For its purpose, I feel this is a good model, and one that can be modified as needed and additional sources of data acquired. The modeling presented does not place any of the results into the larger landscape-to-regional context. I assume that additional modeling is taking place to address regional habitat loss and other impacts. The one possible idea that seems reasonable given the data would be to separately consider the arrival rate and transit

duration as described above. On the whole, I feel the modelers have made good choices and ones that I would likely have made in the same situation.

Barrios, L., and A. Rodríguez. 2004. Behavioural and Environmental Correlates of Soaring-Bird Mortality at On-Shore Wind Turbines. Journal of Applied Ecology 41:72–81. British Ecological Society.

Drewitt, A., and R. Langston. 2008. Collision effects of windpower generators and other obstacles on birds. Annals of the New York Academy

Fargione, J., J. Kiesecker, M. Slaats, and S. Olimb. 2012. Wind and Wildlife in the Northern Great Plains: Identifying Low-Impact Areas for Wind Development. PloS one.

Lucas, M. de, M. Ferrer, M. Bechard, and A. Muñoz. 2012. Griffon vulture mortality at wind farms in southern Spain: Distribution of fatalities and active mitigation measures. Biological Conservation.

Newton, I. 2007. Weather-related mass-mortality events in migrants. Ibis 149:453–467. Blackwell Publishing Ltd.

Nygård, T., and K. Bevanger. 2010. A study of the White-tailed Eagle *Haliaeetus albicilla* movements and mortality at a wind farm in Norway. Climate Change and Birds.

Whitfield, D. 2009. Collision avoidance of golden eagles at wind farms under the “Band”collision risk model. Report from Natural Research to Scottish Natural …:1–35.

COMMENTS FROM REVIEWER 4

February 7, 2013 (Revised March 14, 2013)

1.0 Introduction

The purpose of this review is to provide a formal, independent, external scientific peer review of the U.S. Fish and Wildlife Service (Service) eagle model for predicting fatalities at wind energy facilities in the U.S., and the application of this model to both a proposed 1000 turbine wind project and a second, smaller, more typical, wind facility example of 90 turbines.

1.1 Background

As part of the U.S. Fish and Wildlife Service (Service) Eagle Conservation Plan Guidance (ECPG), the Service developed a Bayesian model to predict the annual fatality rate for bald and golden eagles at a given wind energy facility. This Service model defines the relationship between eagle exposure, collision probability, and fatalities, while accounting for uncertainties. The Service model is intended to provide a foundation for modeling fatality predictions from eagle exposure to hazards posed by wind turbines, because the actual relationships among eagle abundance, fatalities, and their interactions with factors that influence collision probability are still poorly understood. Further, the Service model serves as a basis for learning (i.e., an adaptive framework) and should provide a conservative benchmark when exploring other candidate models that attempt to incorporate additional variables and complexity. Through an adaptive management framework, the Service intends to refine the model with updates and improvements over time.

Given both the current and future use of the Service eagle fatality model to predict both bald and golden eagle fatalities associated with proposed wind energy development projects throughout the U.S., the model and its application in predicting eagle fatalities would benefit from a formal, external, independent, scientific peer review to assess both its scientific validity and whether the Service is using it in an appropriate and unbiased manner as applied to both large and small wind energy projects. The Service desires to use the most scientifically valid and robust model in predicting eagle fatalities at wind energy facilities and to ensure the model is appropriately applied. Therefore, if the peer review demonstrates ways in which the existing model can be improved, this outcome is of great benefit to the Service.

The Service eagle model and all related documents and files, the ECPG the ECPG Module 1- Land-based Wind Energy Technical Appendices (August, 2012), , and all data and files associated with the 2 specific wind energy development examples were provided solely for the purpose of a pre-dissemination peer review under applicable information quality guidelines. Until it is made public, no information from the Service eagle model review may be released by the contractor(s) without express written permission from the Service.

1.2 Peer Review Approach

The Service would like peer reviewers to review the approach and assumptions the Service used in developing the eagle fatality model. In order to meet the Service's objectives of this review, the review will address the following (1) the scientific merit, assumptions, and statistical rigor of the eagle fatality model itself, which provides the basis for annual eagle fatality predictions at individual project sites, (2) application of the model to the 1000 turbine wind energy project given available data and the juxtaposition of this project within its respective landscape, and (3) application of the model to a smaller, more typical, 90 wind turbine project example. Each reviewer must ensure that any scientific uncertainties (or data insufficiencies) are clearly identified and characterized, and the potential implications of the uncertainties for the

technical conclusions drawn are clear. Each modeling reviewer will conduct the model review independently but will later interact with all reviewers looking at eagle risk and impacts to produce the overall review. During the follow-up question phase, the Service will have the opportunity to pose questions to individual reviewers or the reviewers collectively as a team.

2.0 Peer Review Questions

The peer reviewers must consider and respond to the questions listed below, at a minimum, in their reviews. Additional comments can be added in Section 2.4.

2.1 General Model Review Questions

1. *Is the Service eagle fatality model for predicting eagle fatalities at wind energy facilities a scientifically and statistically valid approach for this intended purpose?*

It appears to be valid. In general I find the model to be appropriately cautious and notable for generally using some of the best available information on risk. The Service acknowledges that many of the parameters they try to estimate are poorly known and the resulting Bayesian model allows for adaptive management to incorporate knowledge as it comes in. I think it is a bit silly to ask for more than that, in terms of parameterizing a model.

I do have a number of concerns about the model and its implementation generally and in specific, those are discussed later in my review. In general though it is worth noting that the bulk of these concerns are issues that would make the model insufficiently conservative and that would result in an exercise of even more caution in permitting. These concerns would also provide solid justification for the conservative approach that the Service is taking in interpreting model outputs.

2. *Is the Service eagle fatality model based upon the best available science? If any instances are found where the best available science was not used, please provide the specifics of each situation.*

For the most part, yes. Again, there are a number of characteristics of the natural history of golden eagles that may cause this model to underestimate effects on eagle populations. Many of these are covered in sections below.

With specific regard to the literature, my one comment is that the bulk of the citations in the eagle review and explanation for the model are based on literature that is a few years old. I recognize that these documents take time to produce and, for example, the “Eagle Conservation Plan Guidance” was originally written several years ago. Nevertheless, it may be worth reviewing a few of the more recent peer-reviewed papers and attempting to insert these citations to make that document a hair more current. In particular there have been good papers on risk at wind farms from Spain, eagle flight behavior from eastern North America and some good stuff on lead poisoning and the threat it presents. The Service knows of this work (some is cited in the draft Technical Appendices) but I can provide citations if needed.

3. *Are the methods and assumptions that underlie the Service eagle model clearly stated and logical? If not, please identify the specific methods and assumptions that are unclear or illogical. Also, are these methods and assumptions based on the best available scientific information?*

For the most part, yes. There are several assumptions that I question, but they are among the most difficult of assumptions to remedy and I'm not sure that there is a better way to handle these assumptions than the way the Service has. In nearly all cases, altering these assumptions would call for even more caution and more conservative decision making in predicting fatality rates.

The assumptions that worry me are:

1. The assumption of no age structure in the population. All eagles are the same to this model. Nevertheless, that is almost never the case. Breeding adults are much more difficult to replace than non-breeding floaters. A simple and unrealistic way to address this would be to value summer mortality more than winter mortality (biologically flawed, but feasible and, from an academic perspective, worth exploring). Another way to evaluate these effects is through simulation modeling. Alternatively, we could predict mortality based on known age structure models and then value different birds differently (this would change the current model by making all pre-breeders = 1 eagle and an adult eagle = multiple eagles). The end result of this adjustment would be to make the current model underestimate the effect of certain mortalities.

2. Along the same lines, the current model assumes that all eagle minutes are the same and demographic consequences are independent of density. Thus, in the model, 100 minutes by 1 eagle are similar to 1 minute by 100 eagles. That is true from a risk perspective but not from a demographic perspective. Another way to say this is that risk to territorial birds should have more demographic consequences than risk to non-territorial floaters and that is not currently in the model. This problem is similar but not identical to problem #1.

3. The model currently assumes that replacement is instantaneous and equal. Thus, if one eagle is killed, another eagle of equal demographic value replaces it instantaneously. This is true in an "ideal free" population but not in reality. We know from mammal literature (Goodrich & Buskirk, Cons. Bio 1995, 9(6):1357-1364), for example, that if you kill 1 dominant breeding predator, you can see increases in numbers of sub-dominant individuals at the same site. This issue is not as well explored with birds, but it makes intuitive sense that it would occur. If true, then replacement of dominant territorial adults is by sub-dominants who are both less effective breeders and who occur at higher densities. This would therefore mean that fatality of breeders causes increase in both risk of future fatality for other birds and also greater demographic perturbation than currently expected by the model. Again, this is similar to the problems identified in #1 and #2 above but it is not identical to these problems.

4. Scale effects are not considered. The model assumes that processes occurring at a small, local scale (say, perhaps for a 20-turbine facility) are identical to those that would occur at a large, regional scale (say, perhaps for a 1000-turbine facility). I suspect that the problems that I've noted above – age structure, instantaneous and equal replacement, no density response – and many others are minimally relevant to a tiny project but especially consequential at large scale for a 1000-turbine project. Thus the model is likely reasonable and appropriate for a small-scale wind facility but likely less effective and more likely to be off-base (probably in terms of underestimating mortality) for a larger facility.

5. Cumulative effects are not considered. This may be the greatest weakness in the model but it is also the most easily remedied with change external to the model, by FWS making regional-scale permitting decisions and capping regional take. Most eagle populations can almost certainly handle take of 1 eagle per year but if that take is repeated 20 times over a landscape, it may have dramatic consequences. This is related to but separate from the scale effects consideration noted above and it is critically important to consider.

6. Construction and monitoring effects. The model assumes that pre-construction site visits, construction and post-construction monitoring and maintenance, as well as any other activity involved with evaluating, monitoring and operating wind turbines have no effect on eagles. This is incorrect. Visits to a site by the large equipment required to build a turbine can impact eagle nesting, wintering and even migration biology. The Service should find a way to address this issue in its permitting processes. A similar impact was found in Norway, at Smola, although largely because the eagles were all killed and thus there were fewer eagles using the space (territories became less good once turbines were in place). See Lie Dahl et al. 2012. Reduced breeding success in white-tailed sea eagles at Smola windfarm, western Norway, is caused by mortality and displacement. Biological Conservation 145: 79-85.

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4. *Are the model program files in R code used to calculate the Service eagle model results accurate? If not, please identify any programming errors and the specifics of each error.*

This is outside my area of expertise and I have no comment on this issue.

5. *How can the Service model be improved? Please identify any options to strengthen the scientific foundations of the model.*

Certainly by addressing the unmet assumptions noted above – the assumptions of no age structure, that all flight minutes are identical, that replacement is instantaneous and equal, that scale doesn't matter, that cumulative impacts are not relevant.

An improvement that might be useful is a sensitivity or elasticity analysis. I'd like to understand how the model responds to changes in various model parameters. I'd suggest that instead of a classical sensitivity analysis (which focuses on small changes in parameter values) that all parameters be stepped over a wide range of inputs and then that hordes of simulation runs be conducted to evaluate the impact of those changes on model output. Such an evaluation would be important to making my review of the model more effective.

Another area that would be useful is in preparing the priors for fatality estimates. I understand that the Whitfield 2009 paper is one of the few that estimates fatality rates, but I think that there may be other ways to build these estimates. For example, Grainger Hunt has published (in grey literature) papers discussing fatality rates of golden eagles at Altamont. It would be appropriate to estimate fatality rates for Altamont and plug them into this model. That could then be a "worst case scenario" for a facility and posterior probabilities would then be adjusted down. However, such an approach would encourage conservatism in predicting fatality rates of eagles at facilities that FWS is considering to permit.

That being said, these are additions that would strengthen an already strong model.

6. *Are there any significant peer-reviewed scientific papers that relate to the assumptions of the Service eagle model where consideration of these papers would enhance the scientific quality of the model? Please identify any such peer-reviewed papers and state specifically why incorporation of these ideas would improve the Service model.*

There are only a few papers, as noted above. These include only some recent papers on risk at wind farms from Spain, eagle flight behavior from eastern North America and some good stuff on lead poisoning and the threat it presents. Also some of the papers on the consequences for

local population size of killing dominant predators would be good to include. One of these is noted above. See Goodrich & Buskirk, Cons. Bio 1995, 9(6):1357-1364.

7. *Are there any specific improvements or changes to the Service eagle model that would improve our ability to predict eagle fatalities at wind facilities? Please identify (1) what these changes would be to strengthen the scientific foundation of the model, and (2) any peer-reviewed scientific literature to support these suggested improvements or changes. In responding to this question please bear in mind that the Service does not have the latitude to require wind project proponents to collect the exact type or amount of data we would like in order to run the model, nor to specify the exact methods used to collect these data. Hence, the Service model represents a balancing act that approaches the overall issue more generally, resulting in a model that has fewer parameters than would be ideal.*

Again, the changes noted above would be good. Sensitivity analysis is very important. It would also be extremely valuable to find mechanisms to improve parameter estimates for parameters that are currently unknown. For example, at a specific site it would be feasible to deploy high-frequency GPS telemetry systems to monitor behavior of eagles. This would allow developers or the Service to more effectively predict the risk to eagles from turbines locally. Such mechanisms provide greater detail on the flight behavior of eagles than can be captured by observers.

Hal Caswell's book (Matrix Population Models) and Morris and Doak (Quantitative Conservation Biology) should both have some information on this. The essential idea of sensitivity analysis is to run the model thousands of times making small changes in key parameters. You can then evaluate what small changes have the largest impacts on model outcomes and use that to guide both future data collection and subsequent analyses and model runs. Two papers with sensitivity analyses include

Katzner, T., E.J. Milner-Gulland and E. Bragin. 2007. Using modeling to improve monitoring of structured populations: are we collecting the right data? Conservation Biology 21(1): 241-252.

Katzner, T., E. Bragin and E.J. Milner-Gulland. 2006. Modelling populations of long lived birds of prey for conservation: a study of Imperial Eagles (Aquila heliaca) in Kazakhstan. Biological Conservation 132: 322-335.

2.2 1000 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 1000 wind turbine project in south central Wyoming.

1. *Was the Service application of the eagle fatality model for the proposed 1000 turbine wind energy project accurate and scientifically unbiased given available data? Are the assumptions in the Service model applicable to the project and its juxtaposition within the landscape? If not please explain specific changes the Service should make in applying the eagle model, including its assumptions.*

I feel that the application of the model is accurate and unbiased to the reasonable extent possible given the available data. It would be useful to predict risk more effectively by collecting better flight information on the eagles at this site. However, given circumstances, risk evaluation may be only possible post-exposure by evaluating fatalities after construction.

I think that the model probably does a poor job of scaling up to large facilities and it is entirely likely that demographic impact will be higher than the model predicts, given the current input data. This is a massive proposed facility and there are far more opportunities for estimates of demographic impact to be low than for those estimates to be high. The comments provided above about the underlying assumptions would all make model estimates low and the only one that would make model output an overestimate is a reduction in the collision rate.

Given the fairly large number of active eagle territories near this facility, I am especially concerned about the assumptions related to age structure within the population and the consequences of potentially killing breeding adult eagles (these were assumptions #1 and #3 noted above; #2 could also be relevant to this). Understanding the consequences of violations of those assumptions would be important to predicting consequences to eagle populations from mortality from this facility.

It would be useful to evaluate the model output in the context of a sensitivity analysis.

Finally, as was noted in our initial conference call, eagles forage well before sunrise and well after sunset. Because light is poor, birds may be especially prone to collision during those hours. An eagle day should start about 90 min before sunrise and end about 90 min after sunset, to account for real eagle behavior. Including this in the final fatality estimates would increase fatality rates and be more realistic in regards to eagle behavior.

2. *Please assess the eagle use survey data provided to the Service by the proponents of the proposed 1000 turbine wind energy project, for use in running the eagle model to predict annual eagle fatalities at the project site. Given the size of the project footprint, is the available data sufficient to assess potential eagle impacts? If not, in your expert opinion what additional data is both spatially and temporally necessary for use in running the eagle model to best predict annual eagle fatalities? What are the scientific consequences of lacking such data in the analysis?*

The data appear inadequate to assess potential eagle impacts. I base this judgment on a rather simple analysis of the data that I conducted.

First, there is a difference in the number of observation minutes conducted in each season. If sampling is uneven across these seasons, it may hide between-season variation that would be important to understanding eagle use of the site. This is especially important if the encounter rate is not constant in all seasons – if there are more or less eagles at specific times of the year, it is critical that sampling be constant so that effective comparisons can be made.

Second, there were differences in the mean number of eagles observed per minute in each season. Far more concerning are the rather large differences in the variance between seasons for eagle flight minutes observed, the large coefficient of variation (CV) of these measurements and the large variability in the CV. Please note that the CVs for total minutes of observation conducted are reasonable (around 5-10%) and essentially an order of magnitude smaller than many of the CVs for eagle flight minutes observed (60-180%), especially summer and winter. These problems hold whether we consider the 800-m or 6400m sampling radius. I've pasted in a table showing the mean, standard deviation and CV in each season (Fig 1).

Fig 1. Mean, SD and CV of total minutes observed and of total eagle flight minutes observed at the 1000-turbine project at 800 and 6400m. Note the large CV for flight minutes observed and the large interseasonal variability in standard deviation and CV. This is problematic and suggests that inadequate data were collected at the site.

	Total Minutes Observed			Flight Minutes Observed (800m)			Flight Minutes Observed (6400m)		
Season	Mean	STDEV	CV	Mean	STDEV	CV	Mean	STDEV	CV
Fall	3428.40	317.76	0.093	0.00447	0.00436	0.976	0.00796	0.00463	0.581
Spring	3344.40	392.26	0.117	0.00576	0.00552	0.958	0.00494	0.00314	0.635
Summer	710.20	28.62	0.040	0.00651	0.01059	1.627	0.00397	0.00711	1.792
Winter	1250.36	310.15	0.248	0.00807	0.01034	1.281	0.01574	0.01677	1.066

South-central Wyoming is known to be important for breeding eagles, for non-breeding floaters, and probably for wintering eagles (I suspect this is annually variable depending on winter intensity). The observation data collected for the 1000-turbine project support this interpretation of the importance of the site. Eagle encounter rate (number of minutes eagles were observed) is relatively low in summer, fall and spring, all consistent with this being an important eagle breeding area where dominant territorial birds exclude other eagles during the summer breeding season. Interestingly observation rate peaks in winter, suggesting that either detection rate or numbers increase during winter and implying that this is important wintering habitat for many birds (nb: change in detection rate this could be caused by changes in flight behavior if birds fly lower in winter when lift is less, but such a change would also increase risk to birds).

The seasonal variation in observation rate and in the coefficient of variation is concerning to me. I'm especially bothered that the season that has the highest mean encounter rate (winter, at 800 or 6400m) also was sampled the second least and has the highest variance. Likewise, summer, which has the second highest mean encounter rate (800 m) was sampled the least and has the highest coefficient of variation.

A complete and sufficient data set would, in my mind, have more equal sampling among seasons and, more importantly, constant and reasonable variances and coefficients of variation. The data set as it currently stands is likely to misunderstand eagle use of the region in biologically important times of the year (summer and winter, especially) when eagle use and risk to birds may both be highest. This misunderstanding is most likely going to cause an underestimate of eagle use, but reality is hard to estimate unless we can sample more effectively and reduce variance and CVs. The current data set cannot be used to interpret intra-seasonal variability because there is too much variation in the amount of time spent collecting data. It might be reasonable to clump all data together and make some broad statements, but those broad statements would be driven by certain times of year and would be probably incorrect when more useful data were collected.

Even if eagle use is highly variable, there should not be such variation in number of minutes sampled. This is a massive wind project and there is a burden of proof on the consultants to show that it won't cause harm. The burden is therefore on them to collect data in a useful manner.

3. *What would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers related to eagle behavior or ecology, as they relate to model assumptions, and model application on a project of this scope.*

A more temporally effective sampling would be most important here. (I'm assuming that the spatial distribution of sampling is effective, which it appears to be). Additionally, a sensitivity analysis would help to interpret the model and to make suggestions on better ways to design or collect data for the model.

4. *There are other existing and proposed wind energy facilities within the same local area population of golden eagles where the proposed 1000 turbine project would be developed. The landscape in which the 1000 turbine wind project is proposed is highly rated in terms of its wind energy potential and is used by eagles for breeding, wintering, and migration. Given this backdrop, what scientific factors should the Service consider when assessing potential impacts to eagle populations?*

This is of critical importance. The impact of the 1000-turbine project is likely to be large. However, even a massive project such as this may have limited demographic impact if mortality it causes is compensatory – that is, it happens to birds that, from a demographic perspective, would have died anyhow. This can happen if a site becomes a sink (for example, as Altamont likely is, mortality at Altamont is presently exceeding that expected from compensatory effects). However, if a site is to become a sink, it is important that there be a source to offset that sink. In this case, such a source would have to be the region around the 1000-turbine project. If there are additional wind turbines in the region of the 1000-turbine project then the chances are good that mortality there would go beyond compensatory into the additive range and result in population decline.

This issue gets to the problem of cumulative effects that I have outlined previously in the discussion of unmet assumptions of the model. Cumulative effects go beyond those of any one project and I would strongly encourage the Service to consider seriously and implement mitigation for cumulative effects in their permitting process. This is a critical issue of huge importance to eagle conservation nationally and it cannot be addressed solely with a single fatality model implemented repeatedly for multiple different sites. In an ideal world there should be some type of global demographic model to consider these processes. Alternatively, the Service could use a thought model that is carefully laid out and justified to account for cumulative effects expected from multiple wind facilities in a single region (or in the range of a single sub-population of eagles).

The approach in Appendix F is a step in the right direction. Using the BCRs as a starting point is probably not the best way to do things (although I think the Service recognizes this and is trying to improve on this approach). Appendix F could be improved if demographic structure and types of birds killed were considered – adults, subs, juveniles, etc. In this case, I think the 1000 turbine project may eat up a great deal of the 5% of annual production that would be allowed locally.

2.3 90 Turbine Project Review Questions

Answer these questions with respect to applying the Service model to a proposed 90 wind turbine project.

1. *Was the Service application of the eagle fatality model for the 90 turbine wind energy project example accurate and scientifically unbiased given available data? If not please explain specific changes the Service should make in applying the eagle model to this example.*

Yes. I think the model is especially appropriate for a relatively small facility such as this, where non-linear scale effects are less relevant than at a much larger facility and where cumulative impacts are more easily assessed. Note that my previous comments about unmet assumptions still matter even for this small facility.

2. *Are there any significant peer-reviewed scientific papers that relate to the application of the eagle model to the 90 turbine wind project example, where consideration of these papers would enhance the scientific quality of the outcomes of the model for this project? Please identify any such peer-reviewed papers.*

Few of which I am aware, other than those mentioned previously in the review.

3. *Is the modeling approach used for the 90 wind turbine project sufficiently conservative, in terms of the Service goal of maintaining stable or increasing eagle populations in this example landscape?*

It is my sense that the model scales well to a relatively smaller facility such as this. I have far greater concerns about the suitability of the model for a very large facility, as I suspect the model may severely underestimate fatality at such a large facility. An abundance of caution is called for at a larger facility where the impacts are much harder to predict. A smaller facility such as this one is easier to reconcile with a model that predicts only local impacts and that is unlikely to have broad and far-reaching consequences for eagle demography over a massive part of their range.

2.4 Other Review Questions/Comments

I have no comments that are not addressed above.

3.0 Conclusions and Recommendations

Overall I find this to be a useful model for understanding potential impacts to eagles of wind energy facilities. There are a number of ways that the model could be improved to more accurately assess the impact of fatalities on eagles. These include:

- Building in non-linear scale effects that will likely make large facilities more prone to cause demographic impacts on eagles than small facilities.
- Build in measures of cumulative impacts, or at least account for those cumulative impacts in a thought model to evaluate permitting decisions.
- Address other assumptions – instantaneous replacement, all eagle minutes are identical, lack of age structure, etc.
- Conduct a sensitivity analysis or something similar to simulate and explore the impact of changes in parameter value on model output.

The application of the model to the 1000-turbine project seems appropriate, although this too could be improved. In particular, the things I would suggest addressing beyond the theoretical concerns above include:

- The temporal inadequacy of the sample collection, as indicated by the large standard deviations and the large coefficients of variation.
- Perhaps find a way to incorporate scale effects into this application of the model; I fear that impacts of a massive facility such as this may increase non-linearly with negative consequences for eagles at a much larger scale than those anticipated by the model (for example, if the site becomes a sink for eagles, without a concomitantly large source nearby).
- Find a way to build cumulative effects into either model outcomes or permitting decisions.

I have fewer practical concerns about the application of the model to the smaller 90-turbine facility, as there are few of the scale impacts that are relevant to the larger 1000-turbine facility. The theoretical concerns still apply to this smaller facility.

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APPENDIX C

Reviewer's Resumes
for the
Peer Review of the Eagle Fatality Model
and its
Application to Wind Energy Development Projects
for the
U.S. Fish and Wildlife Service

Bryan Bedrosian

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307.690.2450

Current Position

Craighead Beringia South, Kelly, WY – *Avian Program Director* **2001 – Present**
Primary responsibilities include research project design, employee oversight, coordination, field work, data analysis, manuscript and report preparation, and fundraising.

Education

University of Wisconsin- Stevens Point	B.S. (Biology)	2001
Arkansas State University – Jonesboro, WI	M.S. (Biology)	2005

Research Projects

Common Raven Ecology in Jackson Hole – Principle Investigator 2001-Present
Primary objectives include finding the causes of historical changes in nesting densities, population size estimates, seasonal and annual home ranges through satellite and GPS telemetry, post-fledging ecology, and predation influences on Greater Sage Grouse.

Raptor Ecology and Historical Trends - CO-Principle Investigator 2001-2003
Building on a dataset back to 1948, this project addresses historical trends in nesting densities of raptors, owls, and ravens in Grand Teton National Park.

Lead Ingestion in Avian Scavengers - CO-Principle Investigator 2004-Present
Project is designed to assess the level of lead ingestion by Common Ravens, Bald Eagles, and Golden Eagles from rifle ammunition in Grand Teton National Park and the National Elk Refuge. Current trajectory of the project is focused on national education of hunters and the general public.

Golden Eagle Migratory Behavior – CO-Principle Investigator 2006-Present
A collaborative project between Craighead Beringia South and Raptor View Research Institute, project objectives are to document migratory pathways, stop-over sites, wintering sites, and fidelity of adult golden eagles migrating through central Montana. Project involves satellite tracking.

Sage Grouse Ecology – Principle Investigator 2007-Present
Project objectives include identifying critical winter habitat, productivity, mortality, seasonal movements and home ranges. Developed new techniques for fitting sage grouse with solar, GPS transmitters that would not influence survivorship or behavior and daily tracking of VHF outfitted grouse. Genetic isolation in Jackson Hole, Gros Ventre, Bondurant, and Pinedale populations is also being assessed.

Golden Eagle Demographics in south-central Montana - Principle Investigator 2010-Present
A multi-year study to assess long-term golden eagle nesting density, productivity and prey selection over 60 years. The project is utilizing GPS transmitters to assess home-range, movement and habitat selection as it relates to wind energy development and siting. The project also involves tracking of juvenile Golden Eagle to assess dispersal and winter habitat use.

Hybrid satellite GPS, downloadable transmitter manufacturing – Principle Investigator 2011-Present
As Principle Investigator on a National Science Foundation Grant, a new innovative transmitter is being designed for wildlife research that will be more readily available for biologists and less expensive that current transmitters on the market. Will be available for sale through Craighead Beringia South.

Behavior of Common Ravens in Sage-Grouse Habitat – Cooperator 2012-Present
A collaborative project between Craighead Beringia South and Hayden-Wing Associates, this project is designed to assess potential impacts to breeding sage grouse from breeding Common Ravens in south-central Wyoming

Golden Eagle Distribution, Abundance, and Winter-Range – Principle Investigator 2011-Present
A multi-year project designed to investigate winter-range habitat use of juvenile and sub-adult Golden Eagles across eastern Montana and the Dakotas, this project employs the use of satellite tracking devices and GIS modeling. Also included are large-scale temporal aerial surveys of abundance and distribution of eagles across the study area.

Great Gray Owl Habitat Use and Demographics – Principle Investigator 2012-Present
This project is to conduct a thorough demographic and habitat use study of the sensitive species, Great Gray Owl, at the southern extent of its boreal forest range in the southern Yellowstone Ecosystem where threats of global climate change and prescribed fires threaten population persistence.

Raptor Migration Patterns from Grand Teton National Park – Collaborator 2010-Present
A collaborative project with Grand Teton National Park, this project highlights key migratory behaviors and routes of raptor species both breeding in and wintering in Grand Teton National Park by using satellite telemetry and GIS-based modeling.

Bald Eagle Habitat Use in Relation to Energy Development – CO-Principle Investigator 2011-Present
This collaborative project with Wyoming Game and Fish Department is measuring movements, roosting behaviors and habitat use in a large-scale coal-bed methane gas field currently in production.

Peer Reviewed Publications

Bedrosian, B. E. 2005. Nesting and post-fledging ecology of Common Ravens in Jackson Hole. M.S. Thesis. Arkansas State University, Jonesboro, AR

Bedrosian, B and D. Craighead. 2007. Evaluation of techniques for attaching transmitters to Common Raven fledglings. Northwestern Naturalist. 88:1-6.

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Bedrosian, B., J. Loutsch, and D. Craighead. 2008. Using morphometrics to determine the sex of Common Ravens. Northwestern Naturalist. 89:46-52.

Bedrosian, B., D. Craighead, and T. Rogers. 2008. Record mass for North American Golden Eagle. Journal of Raptor Research. 42:156-157.

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Bedrosian, B. and A. St. Pierre. 2007. Frequency of injuries in three species of wintering raptors in Northeast Arkansas. Wilson Bulletin. 119:296-298.

Bui, T.D., J.M. Marzluff, and B. Bedrosian. 2010. Common raven activity in relation to land use in western Wyoming: implications for greater sage-grouse reproductive success. Condor 112:65-78

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Published Reports

Bedrosian, B., R. Cradall, M. Reuhman, and D. Craighead. Sage-grouse project completion report 2007-2009. 126pp. Dec. 2010

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Crandall, R, B Bedrosian, and D Craighead. Critical winter range movements and habitat of sage-grouse in Jackson Hole, WY. 41 pp. 2010.

Wightman, C, B Bedrosian, A Begley, J Berglund, and A Harmata. 2012. Montana Golden Eagle management guidelines. *Draft Nov. 2012*

Bryan Bedrosian

Reviews

EIS – Hermosa West Wind Project 2012
Professional Publications for Journal of Raptor Research (3), Journal of Wildlife Management (2), Journal of Field Ornithology (2), Condor (1), Wilson Bulletin (1)

Professional Appointments

- President, The Wildlife Society; Wyoming Chapter 2011-2013
- Board Member, Nature Mapping Jackson Hole 2010-Current
- Member, Montana Golden Eagle Working Group 2011-Current
- Member, Natural Resources Technical Advisory Board, Teton County, WY 2012-2014
- Member, Jackson Hole Airport Wildlife Damage Management Advisory Board 2012
- Founder, Wildlife Unleaded 2012-Current

Certified Training

U.S. National Bird Banding Laboratory Certified Net Launcher Trainer
U.S. National Bird Banding Laboratory Certified Trainer for Affixing Raptor Transmitters

Business Experience

Owner/Founder – Trapping Innovations, LLC Founded 2009
Invented and started a business manufacturing safe and effective wildlife net launchers used primarily for eagles and other birds. Oversee all operations, sales and production.

Other Professional Collaborations

- 2009, 2010 Institute for Zoo and Wildlife Research; Berlin, Germany Capture of White-tailed Sea Eagles for a wind farm research project
- 2009 Jackson Hole Airport; Jackson, WY Documented behavior of lekking sage-grouse and associated females. Mapped detailed on-the-ground vegetation structure within the airport for grouse.
- 2010 National Geographic Society; Okeechobee, FL Capture of alligators
- 2011 Norwegian Institute for Nature Research; Olso, Norway Capture of White-tailed Sea Eagles for a wind farm research project
- 2011, 2012 Cimmeron National Grassland; Developed a technique for outfitted Lesser Prairie Chickens with satellite GPS transmitters

Professional Presentations

2012
- Status of Golden Eagles in the West and conservation needs; The Wildlife Society, WY Chpt

2011
- Lead exposure and mitigation techniques for Bald Eagles; The Wildlife Society, National
- Mitigation techniques for lead exposure in eagles and ravens; The Wildlife Society, WY Cpht

2010
- Lead exposure to eagles from ammunition; Raptor Research
- Lead exposure from rifle ammunition in avian scavengers; The Wildlife Society; MT Chpt

2009
- Sage-grouse demographics and habitat use in Jackson Hole, WY; American Ornithological Union
- GPS Transmitters: Technology and uses for avian projects; American Ornithological Union

2008
- Lead exposure in avian scavengers; Midwest Fish and Wildlife Conference

2003
- Nest re-use rates of raptors in Jackson Hole, WY; Raptor Research Foundation

2002
- Post-fledging ecology of Common Ravens in Jackson Hole, WY; American Ornithological Union

Recent Grants & Fundraising (2010-2012)

2012

- Great Gray Owl Demography and Movements in Jackson Hole, WY; WY Game & Fish	$146,000
- Common Raven movements in sage-grouse habitat; Hayden-Wing Assoc.	$42,000
- Golden Eagle distribution and abundance in eastern MT; BLM	$35,000
- Modeling sage-grouse critical habitat in Jackson Hole; USRBSGWG	$9,000
- Sage-grouse genetic analysis within Jackson Hole, WY; UWYO-NPS	$3,000
- Golden Eagle nesting demography in south-central MT; Cinnebar Foundation	$2,000
- Private Individuals	$57,000

2011

- Golden Eagle distribution and abundance in eastern MT; BLM	$115,000
- Bald Eagle habitat use within an oil and gas field; WYGFD/PAPO	$60,000
- Common Raven movements in sage-grouse habitat; Hayden-Wing Assoc.	$36,000
- Modeling sage-grouse critical habitat in Jackson Hole; USRBSGWG	$9,000
- Golden Eagle nesting demography in south-central MT; Altria Foundation	$5,000
- Private Individuals	$48,000

2010

- GPS transmitter development; National Science Foundation	$242,000
- Education and mitigation for avian lead poisoning from ammunition; Packard Foundation	$125,000
- Education and mitigation for avian lead poisoning from ammunition; Hewlett Foundation	$30,000
- Sage-grouse genetic analysis; BLM	$30,000
- Private Individuals	$51,000

15 November 2012

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CURRICULUM VITAE

CURRENT POSITIONS

Institution	Title	Year
West Virginia University Division of Forestry and Natural Resources	Research Assistant Professor	2010 – present
Hawk Mountain Sanctuary Association Acopian Center for Conservation Learning	Research Associate	2003 - present
Wildlife Conservation Society International Programs	Research Associate	2000 - present

EDUCATION

Institution	Degree	Year Graduated
Arizona State University	Ph.D. (Biology)	May 2003
Diss. title: *Ecology and behavior of four coexisting eagle species at Naurzum Zapovednik, Kazakhstan*		
The University of Wyoming	M.S. (Zool. & Phys.)	December, 1994
Thesis title: *Winter ecology of the pygmy rabbit (*Brachylagus idahoensis*) in Wyoming.*		
Oberlin College	B.A. (Biology)	May, 1991

Special Programs and Courses	Year
Organization for Tropical Studies (OTS) Tropical Biology - An Ecological Approach	1998
Associated Colleges of the Midwest (ACM) Wilderness Field Station Ornithology, Behavioral Ecology of Vertebrates	1990

AREAS OF SPECIALIZATION

Ecology, Conservation Biology, Ornithology, Mammalogy, Population Biology, Physiological Ecology

HONORS

Conservation Award, Pennsylvania Society for Ornithology. Awarded May 2011
Elective Member, American Ornithologists Union. Elected August 2008.
Student Presentation Award, North American Ornithological Congress, New Orleans, September 2002.
Outstanding Teaching Associate Award. Department of Biology, Arizona State University. May 2002.
Phi Kappa Phi, University of Wyoming, May 1994.
Sigma Xi, Oberlin College, May 1991.

PEER-REVIEWED PUBLICATIONS

51. Katzner, T.E. & N. J. Collar. 2013. Are insular populations of the Philippine falconet (*Microhierax erythrogenys*) steps in a cline? The Condor, *in press*.

50. Брагин Е.А., **Катцнер Т**., Брагин А.Е. 2012. Летние скопления крупных пернатых хищников и проблема оценки их численности// Труды Мензбировского орнитологического общества, том I: Материалы XIII Международной орнитологической конференции Северной Евразии. - Махачкала: АЛЕФ, С. 234-240. [Summer accumulations of birds of prey and the problem of estimating their number. Proceedings Menzbier Ornithological Society, Volume I: Proceedings of the XIII International Ornithological Conference of North Eurasia. - Makhachkala: Pp. 234-240]

49. Evans, D.M., P. Barnard, L.P. Koh, C.A. Chapman, R. Altwegg, T.W.J. Garner, M.E. Gompper, I.J. Gordon, **T.E. Katzner** & N. Pettorelli. 2012. Funding nature conservation: who pays?.*Animal Conservation.* 15: 215-216.

48. Bragin, E.A.& **T.E. Katzner**. 2012. Вторая находка гнезда лутка *Mergus albellus* в Наурзумском бору. *Русский орнитологический журнал*, Том 21, Экспресс-выпуск 743: 724-725. [Second nest record of Smew *Mergus albellus* in the Naurzum forest. *Russian Ornithological Journal, Express Issue*. 21(743):724-725].

47. Sklyarenko, S.L. & **T.E. Katzner**. 2012. Состояние популяций хищных птиц-падальщиков в Казахстане [The status of populations of vultures in Kazakhstan]. Орнитологический вестник Казахстана и Средней Азии.[Ornithological News of Kazakhstan and Middle Asia.] Volume 1. Almaty, 2012. 248 pp.

46. Katzner, T., D. Brandes, T. Miller, M. Lanzone, C. Maisonneuve, J. Tremblay, R. Mulvihill & G. Merovich. 2012. Topography drives migratory flight altitude of golden eagles: implications for on-shore wind energy development. *Journal of Applied Ecology. 49: 1178-1186. doi: 10.1111/j.1365-2664.2012.02185.x*

45. Lanzone, M., T. Miller, P. Turk, D. Brandes, C. Halverson, C. Maisonneuve, J. Tremblay, J. Cooper, K. O'Malley, R. Brooks, & **T. Katzner**. 2012. Stereotyped slight response of migratory raptors to a variable meteorological environment. *Biology Letters, 8:710-713*.

44. Duerr, A., T. Miller, M. Lanzone, D. Brandes, J. Cooper, K. O'Malley, C. Maisonneuve, J. Tremblay, **T. Katzner**. 2012. Testing an emerging paradigm in migration ecology shows surprising differences in efficiency between flight modes. *PLoS ONE 7(4): e35548. doi:10.1371/journal.pone.0035548*

43. Gordon, I.J., K. Acevedo-Whitehouse, R. Altwegg, T.W.J. Garner, M.E. Gompper, T.E. Katzner, N. Pettorelli & S. Redpath. 2012. What the 'food security' agenda means for animal conservation in terrestrial ecosystems. *Animal Conservation.* 15: 115-116.

42. Branch, T.A., J.D. Austin, K. Acevedo-Whitehouse, I.J. Gordon, M.E. Gompper, **T.E. Katzner** & N. Pettorelli. 2012. Fisheries conservation and management: finding consensus in the midst of competing paradigms. *Animal Conservation*. 15: 1-3.

41. Katzner, T.E., M. Wheeler, J.J. Negro, Y. Kapetanakos, J.A. DeWoody, M. Horvath & Irby Lovette. 2012. To pluck or not to pluck: scientific methodologies should be carefully chosen, not "one size fits all." *Journal of Avian Biology. 43: 15-17.*

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39. Borher, G., D. Brandes, J. Mandel., K. Bildstein, T. Miller, M. Lanzone, **T. Katzner**, C. Maisonneuve, J. Tremblay. 2012. Estimating updraft velocity components over large spatial scales: Contrasting migration strategies of golden eagles and turkey vultures. *Ecology Letters. 15: 96-103. doi: 10.1111/j.1461-0248.2011.01713.x*

38. Katzner, T.E., J.D. Winton, F.A. McMorris & D. Brauning. 2012. Dispersal, band recovery and causes of death in a reintroduced and rapidly growing population of Peregrine Falcons. *Journal of Raptor Research*. 46(1): 75-83.

37. Donnelly, R.E., **T. Katzner**, I.J. Gordon, M.E. Gompper, S. Redpath, T.W.J. Garner, R. Altwegg, D.H. Reed, K. Acevedo-Whitehouse & N. Pettorelli. 2011. Putting the eco back in ecotourism. *Animal Conservation.14: 325-327.*

36. Katzner, T.E., J.R. Ivy, E.A. Bragin, E.J. Milner-Gulland & J.A. DeWoody. 2011. Cryptic population size and conservation: consequences of making the unknown known. *Animal Conservation, 14:340-341.*

PEER-REVIEWED PUBLICATIONS (cont.)

35. Katzner, T.E., J.R. Ivy, E.A. Bragin, E.J. Milner-Gulland & J.A. DeWoody. 2011. Conservation implications of inaccurate estimation of cryptic population size. *Animal Conservation. 14:328-332. Feature article, cover photo.*

34. Reyers, B., N. Pettorelli, **T. Katzner**, M. Gompper, S. Redpath, T. Garner, R. Altwegg, D. Reed & I. Gordon. 2010. Animal conservation and ecosystem services: garnering the support of mightier forces. *Animal Conservation. 13: 523 – 525.*

33. Iverson, S., A. Gavrilov, **T. Katzner**, J. Takekawa, S. Newman, T. Miller, W. Hagemeijer, B. Sivananinthaperumal, T. Mundkur, C. DeMattos & L. Ahmed. 2010. Migratory movements of waterfowl in Central Asia: implications for avian influenza transmission by wild birds. *Ibis. 153: 279–292*

32. Pettorelli, N., I. J. Gordon, **T. Katzner**, M. E. Gompper, K. Mock, S. Redpath, T. W. J. Garner & R. Altwegg. 2010. Protected areas: the challenge of maintaining a strong backbone for conservation strategies worldwide. *Animal Conservation* 13: 333–334.

31. Jones, J.P.G., B. Collen, P. Baxter, P. Bubb, J. Illian, **T. Katzner**, A. Keane, J. Loh, E. McDonald-Madden, E. Nicholson, H. Pereira, H. Possingham, A. Pullin, A. Rodrigues, V. Ruiz-Gutierrez, M. Sommerville, E.J. Milner-Gulland. 2010. The 'why', 'what' and 'how' of global biodiversity indicators: looking beyond 2010. *Conservation Biology. 25(3): 450-457.*

30. Terraube, J., Arroyo, B.E., Mougeot, F., **Katzner, T.E.** and E.A. Bragin. 2010. Breeding biology of the Montagu's harrier (*Circus pygargus*) in north-central Kazakhstan. *Journal of Ornithology*. *151 (3): 713-722.*

29. Blackburn, T.M., N. Pettorelli, **T. Katzner**, M. E. Gompper, K. Mock, T. W. J. Garner, R. Altwegg, S. Redpath & I. J. Gordon. 2010. Dying for conservation: eradicating invasive alien species in the face of opposition. *Animal Conservation. 13:227–228.*

28. Gordon, I.J., N. Pettorelli, **T. Katzner**, M. E. Gompper, K. Mock, S. Redpath, T. W. J. Garner & R. Altwegg. 2010. International year of biodiversity: missed targets and the need for better monitoring, real action and global policy. *Animal Conservation.* 13:113-114.

27. Penteriani, V., N. Pettorelli, I.J. Gordon, **T. Katzner**, K. Mock, S. Redpath, R. Altwegg & M.E. Gompper. 2010. New European Union fisheries regulations could benefit conservation of marine animals. *Animal Conservation.* 13:1-2.

26. Pettorelli, N., **T. Katzner**, I. Gordon, T. Garner, K. Mock, S. Redpath and M. Gompper. 2009. Possible consequences of the Copenhagen climate change meeting for conservation of animals. *Animal Conservation* 12: 503–504.

25. Brandes, D., Miller, T.M. and **T. Katzner**. 2009. Wind Power Mortality. *In:* Majumdar, S.K., *ed.,* Avian Ecology and Conservation: A Pennsylvania Focus with National Implications. Pennsylvania Academy of Sciences. pp. 300 – 303.

24. Miller, T.M., Brandes, D., Lanzone, M., Ombalski, D., Maisonneuve, C. and **T. Katzner**. 2009. Golden eagle migration and winter behavior in Pennsylvania. *In:* Majumdar, S.K., *ed.,* Avian Ecology and Conservation: A Pennsylvania Focus with National Implications. Pennsylvania Academy of Sciences. pp 111 - 125.

23. Rudnick, J.A., **T.E. Katzner**, and J.A. DeWoody. 2009. Genetic Analyses of Noninvasively Collected Feathers Can Provide Insights into Avian Demography and Behavior. *in:* Aronoff, J.B., *ed.* Handbook of Nature Conservation: Global, Environmental and Economic Issues. Nova Publishers. pp.181-197.

22. Poulakakis, N., A. Antoniou, G. Mantziou, A. Parmakelis, T. Skartsi, D. Vasilakis, J. Elorriaga, J. De La Puente, A. Gavashelishvili, M. Ghasabyan, **T. Katzner**, M. Mcgrady, N. Batbayar, M. Fuller and T. Natsagdorj. 2008. Population structure, diversity, and phylogeography in the near-threatened Eurasian black vultures *Aegypius monachus* (Falconiformes; Accipitridae) in Europe: insights from microsatellite and mitochondrial DNA variation. *Biological Journal of the Linnean Society. 95:859-872.*

21. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2008. A non-invasive genetic evaluation of population size, natal philopatry, and roosting behavior of non-breeding eastern imperial eagles (*Aquila heliaca*) in central Asia. *Conservation Genetics* 9: 667–676.

20. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2007. Species identification of birds through genetic analysis of naturally shed feathers. *Molecular Ecology Notes 7: 757–762.*

PEER-REVIEWED PUBLICATIONS (cont.)

19. Ryabtsev, V. and **T. Katzner**. 2007. Severe declines of Eastern Imperial Eagle *Aquila heliaca* populations in the Baikal region, Russia: a modern and historical perspective. *Bird Conservation International* 17:197-209.

18. Katzner, T., E.J. Milner-Gulland and E. Bragin. 2007. Using modeling to improve monitoring of structured populations: are we collecting the right data? *Conservation Biology* 21(1): 241-252.

17. Kenward, R., **T. Katzner**, M. Wink, V. Marcström, S. Walls, M. Karlbom, R. Pfeffer, E. Bragin, K. Hodder, and A. Levin. 2007. Rapid sustainability modelling for raptors by radio-tagging and DNA-fingerprinting. *Journal of Wildlife Management* 71(1): 238-245.

16. Katzner, T., E. Bragin, S. Knick and A. Smith. 2006. Spatial structure in the diet of imperial eagles *Aquila heliaca* in Kazakhstan. *Journal of Avian Biology* 37: 594-600.

15. Katzner, T., E. Bragin and E.J. Milner-Gulland. 2006. Modelling populations of long-lived birds of prey for conservation: a study of Imperial Eagles (*Aquila heliaca*) in Kazakhstan. *Biological Conservation* 132: 322-335.

14. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, O.E. Rhodes, Jr., and J.A. DeWoody. 2005. Using naturally shed feathers for individual identification, genetic parentage analyses, and population monitoring in an endangered Eastern imperial eagle (*Aquila heliaca*) population from Kazakhstan. *Molecular Ecology* 14: 2959-2967.

13. Katzner, T. 2005. Corruption - a double-edged sword for conservation? A response to Smith and Walpole. *Oryx* 39(3):260-262.

12. Katzner, T., S. Robertson, B. Robertson, J. Klucsarits, K. McCarty, and K.L. Bildstein. 2005. Increasing the efficiency of conservation efforts: an example using a nest box program for American kestrels (*Falco sparverius*). *Journal of Field Ornithology* 76(3):217-226.

11. Katzner, T., E. Bragin, S. Knick and A. Smith. 2005. Relationship between demographics and dietary specificity of Imperial Eagles in Kazakhstan. *Ibis* 147:576-586.

10. Busch, J.D., **T. Katzner**, E. Bragin and P. Keim. 2005. Tetranucleotide microsatellites for *Aquila* and *Haliaeetus* eagles. *Molecular Ecology Notes* 5:39-41.

9. Leppert, L.L., S. Layman, E.A. Bragin, and **T.E. Katzner**. 2004. Hemoparasite prevalence in Imperial Eagles (*Aquila heliaca*), Steppe Eagles (*Aquila nipalensis*), and White-tailed Sea Eagles (*Haliaeetus albicilla*) from Kazakhstan. *Journal of Wildlife Diseases*. 40(2): 316-319.

8. Katzner, T.E., C.H. Lai, J.D. Gardiner, J.M. Foggin, D. Pearson and A.T. Smith. 2004. Adjacent nesting by Bearded Vulture (*Gypaetus barbatus*) and Himalayan Griffon Vulture (*Gyps himalayensis*) on the Tibetan Plateau, China. *Forktail*. 20: 94-96.

7. Sharkov, A., **T.E. Katzner** and T.M. Bragina. 2003. A new species of *Copidosoma* Ratzeburg (Hymenoptera: Encyrtidae) from eagle nests in Kazakhstan. *Journal of Hymenoptera Research*. 12(2):308-311.

6. Katzner, T., E. Bragin, S. Knick and A. Smith. 2003. Coexistence in a multi-species assemblage of eagles in central Asia. *Condor*. 105: 538-551.

5. Pain, D.J., A.A. Cunningham, P.F. Donald, J.W. Duckworth, D.C. Houston, **T. Katzner**, J. Parry-Jones, C. Poole, V. Prakash., P. Round, and R. Timmins. 2003. Causes and impacts of temporospatial declines of *Gyps* vultures in Asia. *Conservation Biology*. 17(3): 661-671.

4. Katzner, T.E. and Y.P. Cruz. 1998. Survival of the polyembryonic parasitoid *Copidosomopsis tanytmema* (Hymenoptera: Encyrtidae) in envenomized larvae of its host *Anagasta keuhniella* (Lepidoptera: Pyralidae). *Annals of the Entomological Society of America*. 91(6):808-812.

3. Katzner, T.E. and K.L. Parker. 1998. Long distance movements from established burrow sites by pygmy rabbits (*Brachylagus idahoensis*) in southwestern Wyoming. *Northwestern Naturalist*. 79(2):72-74.

2. Katzner, T.E. and K.L. Parker and H.H. Harlow. 1997. Metabolism and thermal response to changes in ambient temperature in winter acclimatized pygmy rabbits (*Brachylaygus idahoensis*). *Journal of Mammalogy*. 78(4):1053-1062.

1. Katzner, T.E. and K.L. Parker. 1997. Vegetative characteristics and size of home ranges used by pygmy rabbits (*Brachylagus idahoensis*) during winter in southwestern Wyoming. *Journal of Mammalogy*. 78(4):1063-1072.

BOOKS, BOOK CHAPTERS, BOOK EDITING

5. Watson, J. 2011. 2nd Edition. The Golden Eagle. *T & A.D. Poyser*. **Contributing author/editor.**
4. Tingay, R.E. and **T.E. Katzner**, eds. 2010. The Eagle Watchers. *Cornell University Press.*
3. Katzner, T.E. and R. E. Tingay. 2010. Eagle Diversity, Ecology and Conservation. *In.* Tingay, R.E. and **T.E. Katzner**, eds. 2010. The Eagle Watchers. *Cornell University Press.*
2. Katzner, T.E. 2010. Eastern Imperial Eagle. *In*: Tingay, R.E. and **T.E. Katzner**, eds. 2010. The Eagle Watchers. *Cornell University Press.*
1. Katzner, T.E. 2008. Downward Spiral: Catastrophic Decline of South Asia's Vultures. pp. 139 – 145 *In:* Fern, E. & Redford, K. H., eds. *2008 – 2009 State of the Wild: a Global Portrait of Wildlife, Wildlands and Oceans.* Wildlife Conservation Society, New York, NY & Island Press, Washington DC.

FELLOWSHIPS AND SCHOLARSHIPS

Estación Biológica de Doñana, Access to the Research Infrastructure Prog. ECODOCA Fellowship. 2004.$1,946.
National Science Foundation, International Postdoctoral Research Fellowship. 2003-2005. $147,750
National Security Education Program, Graduate International Fellowship. 2001. $11,600
Environmental Protection Agency, STAR Fellowship for Graduate Environmental Study. 1998-2001. $94,326.
National Defense Science and Engineering Graduate Fellowship Program. 1997. Honorable Mention.
Reed W. Fautin Memorial Scholarship, University of Wyoming. 1993. $1,100.

GRANTS AND RESEARCH FUNDING

US Bureau of Land Management – California State Office. 2012. Golden eagle demography: genetic approaches to population biology in the face of renewable energy development in the California desert. Co-PI with Andrew DeWoody, Jacqueline Doyle, Phil Turk, Adam Duerr, Tricia Miller, Michael Lanzone and David Brandes. $126,000 ($26,907 through WVU, $99,093 through Purdue University).

Virginia Department of Game and Inland Fisheries. 2012. Bald eagle conservation and management in Virginia. Co-PI with Adam Duerr and Tricia Miller. $295,000.

California Department of Fish and Game. 2012. Data collection and synthesis of current knowledge of golden eagles. Co-PI with Adam Duerr, Trish Miller, Phil Turk & David Brandes. $255,000.

US Bureau of Land Management – California State Office. Golden eagle home range, habitat use, demography and renewable energy development in the California desert (*Grant Modification*). Co-PI with David Brandes, Adam Duerr, Philip Turk, Tricia Miller and Michael Lanzone. $54,390.

RES America. 2012. Assessing Granite Wind for RES America. Co-PI with Trish Miller, Adam Duerr, and Phil Turk. $41,440.

USDA Forest Service, Northern Research Station. 2012. Avian response to fire. Co-PI with John Edwards & Tom Shuler. $15,000. (*continuation of previous award from 2011*).

International Association of Avian Trainers and Educators. 2012. Conservation ecology of the globally threatened red-footed falcon. Co-PI with Evgeny A. Bragin. $2,000.

Quebec Department of Wildlife and Natural Resources. 2012. Trapping and telemetry of golden eagles during winter in Pennsylvania. Co-PI with Tricia Miller & Michael Lanzone. $10,000.

US Bureau of Land Management – California State Office. 2011. Golden eagle home range, habitat use, demography and renewable energy development in the California desert. Co-PI with David Brandes, Adam Duerr, Philip Turk, Tricia Miller and Michael Lanzone. $321,054.

National Birds of Prey Trust. 2011. Conservation ecology of the globally threatened red-footed falcon (*Falco vespertinus*): migration, breeding and winter ecology (Year II). $6,166.

USDA Forest Service, Northern Research Station. 2011. Avian response to fire. Co-PI with John Edwards & Tom Shuler. $25,000.

WVU McIntyre-Stennis Program. 2011. Application of Novel Technologies and Approaches for Enhancing Wildlife Ecology and Conservation. $4,000.

Transportation Research Board of the National Academies. 2011. Pilot Test the Ecological Approaches to Environmental Protection Developed in Capacity Research Projects C06A and C06B. Co-PI with Jim Anderson, Walter Veselka, Michael Strager, Hodjat Ghadimi, Lian-Shin Lin, J. Todd Petty, Daniel Welsch, Todd Miller, Norse Angus, & Laura Conley-Reinhart 2011. $360,628.

National Birds of Prey Trust. Conservation ecology of the globally threatened red-footed falcon (*Falco verspertinus*): migration breeding and winter ecology. Co-PI with Evgeny Bragin. 2010. $7,725.

GRANTS AND RESEARCH FUNDING (cont.)

Virginia Department of Game and Inland Fisheries. Winter ecology and conservation of golden eagles in Virginia. Co-PI with Rob Brooks, Brady Porter, Mike Lanzone, Trish Miller & Maria Wheeler. 2010. $104,300.

US Department of Energy, 20% Wind by 2030: Overcoming the Challenges. Developing high-resolution spatial data of migration corridors for avian species of concern in regions of high potential wind development. Co-PI with Dave Brandes, Rob Brooks, Charles Maisonneuve, Andrew Mack, Trish Miller & Michael Lanzone. 2010. $193,000.

Kick Start Partnership Program. Keystone Innovation Zone Kick Start Grant. 2009. $5,000.

The Technology Collaborative. Development of a universal plug-and-play M2M platform. 2009. $150,000.

Civilian Research and Defense Foundation. Non-invasive ecology, monitoring and conservation of raptors in north-central Kazakhstan. Co-PI with Andrew DeWoody and Evgeny Bragin. 2009-2010. $45,000.

Idea Foundry. Transformation Fellowship Program to Cellular Tracking Technologies, LLC. $40,000.

Pennsylvania Wild Resource Conservation Program. Assessing Genetic Diversity of Pennsylvania's Eastern Golden Eagles: How Unique Are They? Co-PI with Brady Porter. 2008-2009. $33,958.

West Virginia State Cooperative Grant Program. Assessing Genetic Diversity of West Virginia's Eastern Golden Eagles: How Unique Are They? Co-Pi with Brady Porter. 2008-2009. $8,059.

Pennsylvania State Wildlife Grant Program. Assessing risks of wind energy development for a priority "umbrella" species: Pennsylvania's special responsibility for conservation of eastern golden eagles. Co-PI with Dave Brandes, Trish Miller, Robert Mulvihill, Michael Lanzone, 2008-2010. $70,000.

Innovation Works. Emerging Technology Assistance Program. Grant to Cellular Tracking Technologies, LLC, for product development. 2008. $25,000.

Quebec Department of Wildlife and Natural Resources. Telemetry, home range, migration and management of birds of prey in the context of wind energy development. 2008. $23,250.

Wild Bird Global Avian Influenza Network for Surveillance. Monitoring Avian Influenza within and across species in Kazakhstan. 2008. $50,661.

Alexandria Zoological Park. Support for white-tailed sea eagle research. 2008. $1,000.

Association of Zoos and Aquariums - Conservation Endowment Fund. Non-invasive genetic estimation of population size of critically endangered *Gyps* vultures in Asia. Co-PI with Yula Kapetanakos and Nancy Clum. 2007 - 2008. $22,765.

Allegheny Plateau Audubon Society. GPS Telemetry of golden eagles in Pennsylvania. Co-PI with Trish Miller, Dave Brandes, Robert Mulvihill, Michael Lanzone, 2008. $5,000

National Birds of Prey Trust. Molecular ecology and conservation of imperial eagles (*Aquila heliaca*) and white-tailed eagles (*Haliaeetus albicilla*) from Kazakhstan. Co-PI with Andrew DeWoody. 2007-2008. $31,000.

Pennsylvania State Wildlife Grant Program. Assessing conservation needs of eastern golden eagles in Pennsylvania. Co-PI with Dave Brandes, Trish Miller, Robert Mulvihill, Michael Lanzone, 2007-2008. $25,000.

Wild Bird Global Avian Influenza Network for Surveillance. Monitoring Avian Influenza within and across species in Kazakhstan. 2007. $48,360.

National Geographic Society - Committee for Research and Exploration. Non-invasive genetic monitoring of the endangered Eastern Imperial Eagle in Kazakhstan. Co-PI with Andrew DeWoody, Evgeny Bragin and Jamie Rudnick. 2006. $19,850.

Wildlife Conservation Society - International Programs. Ecology and conservation of a unique community of endangered eagles at the Naurzum Zapovednik, Kazakhstan. Co-PI with Evgeny A. Bragin. 2002: $4,845; 2003: $5,700; 2004: $6,270; 2005: $9,416; 2006: $4,840; 2007: $5,000.

Wildlife Conservation Society - International Programs. Status and conservation of vultures in south-eastern Kazakhstan. Co-PI with Sergei L. Sklyarenko. 2001-2002. $8,875; 2003: $5,300; 2004: $5,830; 2005: $5,744; 2006:$5,700; 2007: $5,000.

Wildlife Conservation Society - International Programs. Conservation and monitoring of vultures China. 2005:$5,625.

Graduate College and Department of Biology, Arizona State University. Travel grant. 2001: $1,000, 2002: $514

Wildlife Conservation Society - International Programs, Research Fellowship Program. Ecology and conservation of a unique community of endangered eagles at the Naurzum Zapovednik, Kazakhstan. Co-PI with Evgeny A. Bragin. 2000-2001. $11,650.

The Frank M. Chapman Memorial Fund, American Museum of Natural History. Integrating competition and predation in a unique community of endangered eagles in Kazakhstan. 2000. $2,000.

GRANTS AND RESEARCH FUNDING (cont.)

Northwest Airlines - Travel Support for Research. 2000. $125.

The Graduate College, Arizona State University. Graduate training in the biological sciences: preparing for the future. Co-PI with Dr. Thomas Dowling, Martin Gerrits, Lisa Dent, Jill Welter, Dr. Michael Moore and Dr. James Collins. 1999-2000. $5,880.

Northwest Airlines - Travel Support for Research. 1999. $125.

Biological Resources Division, US Geological Survey: Spatial and temporal relationships between habitats and primary prey of raptors in Kazakhstan. Co-PI with Andrew Smith. 1997-2000. $22,327.

World Nature Association Grant. Conservation alternatives for endangered species management at the Naurzum Zapovednik, Kazakhstan. 1997. $800.

The Frank M. Chapman Memorial Fund, American Museum of Natural History. Raptor conservation studies in a unique ecosystem in north-central Kazakhstan. 1997. $2,000.

The International Osprey Foundation Endowment Fund Grant. Raptor conservation studies in a unique ecosystem in north-central Kazakhstan. 1997. $1,000.

Russian & East European Studies Consortium Travel Grant, Arizona State University. 1997. $500.

Hawk Mountain-Zeiss Raptor Research Award. Raptor conservation studies in a unique ecosystem in north-central Kazakhstan. 1997. $1,000.

Graduate Research Support Program, Arizona State University. Modeling predator-prey dynamics and their interaction with landscape level processes in a unique system in Kazakhstan. 1997. $2,000.

Hughes Student Research Grant, Oberlin College. 1991.

FOUNDATION AND PRIVATE DONOR FUNDING

2012: $31,000 (Golden Eagle Research Support, Research Support, Support for student education)
2011: $25,850 (Golden Eagle Research Support, Research Support, Kazakhstan field station)
2010: $25,000 (Research support, Kazakhstan field station)
2009: $16,500 (Departmental research support, Kazakhstan field station, Urban peregrines)
2008: $20,500 (Departmental research support, Kazakhstan field station, Urban peregrines)
2007: $17,000 (Kazakhstan field station, Departmental research support, Urban peregrines)
2006: $5,000 (Kazakhstan field station)

CONFERENCE PROCEEDINGS & PUBLISHED REPORTS

17. Брагин Е.А., **Катцнер Т.**, Брагин А.Е. 2012. Пространственные связи популяции орла-могильника *Aquila heliaca* островных лесов Костанайской области [The spatial relations of the Imperial Eagle Aquila heliaca population of forest patches of Kostanay Region]. Proceedings of the second international conference on biodiversity of Asian steppes. Kostanay, Kazakhstan, 5-6 June 2012.
16. Katzner, T.E. J.A.R. Ivy, E.A. Bragin, E.J. Milner-Gulland & J.A. DeWoody. 2012. How many eagles are at Naurzum? Proceedings of the second international conference on biodiversity of Asian steppes. Kostanay, Kazakhstan, 5-6 June 2012.
15. Maisonneuve, C., T. Miller, J.A. Tremblay, **T. Katzner**, M. Lanzone and D. Brandes. 2011. Differential vulnerability of Bald and Golden Eagles to wind turbine collision on breeding grounds in Québec. Proceedings of the Conference on Wind energy and Wildlife impacts, 2-5 May 2011, Trondheim, Norway. Roel May and Kjetil Bevanger (eds). NINA Report 693.
14. Tremblay, J.A., C. Maisonneuve, **T. Katzner**, T. Miller, M. Lanzone and D. Brandes. 2011. A case study of the interaction between landscape configuration and habitat use at a wind facility by golden eagles (*Aquila chrysaetos*). Proceedings of the Conference on Wind energy and Wildlife impacts, 2-5 May 2011, Trondheim, Norway. Roel May and Kjetil Bevanger (eds). NINA Report 693.
13. Maisonneuve, C., T. Miller, M. Lanzone, **T. Katzner.** 2009. Studies on threatened species of birds of prey and wind farms in eastern North America. Birds of Prey and Wind Farms: Analysis of Problems and Possible Solution. Documentation of an international workshop in Berlin, 21st and 22nd October 2008.
12. Sklyarenko, S. and T. Katzner. 2008. The black vulture, *Aegypius monachus*, in central Asia. Proceedings of the International Symposium on the Black Vulture *Aegypius monachus*. Cordoba, Spain.

CONFERENCE PROCEEDINGS & PUBLISHED REPORTS (cont.)

11. Bragin, E.A., J. Rudnik, **T. Katzner**, A. DeWoody. 2008. New methods for raptors research: results of research on the imperial eagle in north Kazakhstan. Research and conservation of birds of prey of northern Eurasia. Materials of the 5th international conference on birds of prey of northern Eurasia. Ivanovo, 4-7 February 2008. Ivanovo State University Press. Edited by V.M.Galushin, V.N.Melnikov, A.I.Shretaikov, D.I.Chudnenko. 360 p. In Russian.
10. Bragin, A. **T. Katzner**, P. Sharpe, D. Garselon, A. E. Bragin. 2008. Results of research on imperial eagle migrations from northern Kazakhstan. Research and conservation of birds of prey of northern Eurasia. Materials of the 5th international conference on birds of prey of northern Eurasia. Ivanovo, 4-7 February 2008. Ivanovo State University Press. Edited by V.M.Galushin, V.N.Melnikov, A.I.Shretaikov, D.I.Chudnenko. 360 p. In Russian.
9. Rudnick, J.A., **T. E. Katzner**, and J.A. DeWoody. 2008. Genetic analyses of noninvasively collected feathers can provide new insights into avian demography and behavior. Biological Conservation Research Trends.
8. Katzner, T., E.J. Milner-Gulland and E. Bragin. 2007. Using modeling to improve monitoring of eagles: are we collecting the right data? International Scientific Conference "Biological Diversity of Asian Steppe," Kostanay, Kazakhstan.
7. Risebrough, R.W., M.A. Virani, **T.E. Katzner** and J.W. Duckworth. 2006. Collapse of vulture populations in southern Asia. *In*: Proceedings of the 23rd International Ornithological Congress, Beijing, China. Acta Zoologica Sinica. 52(supplement): 42-43.
6. Katzner, T., A. Gavashelishivili, S. Sklyarenko, M. McGrady, J. Shergalin, and K. Bildstein. 2004. Population and Conservation Status of Griffon Vultures in the Former Soviet Union. Pp. 235-240. *In:* Chancellor, R. D. & B.-U. Meyburg eds. Raptors Worldwide: Proceedings of the WWGBP - 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.
5. Bragin, E. and **T. Katzner**. 2004. Population trends and nesting success of Imperial Eagle, Golden Eagle and White-tailed Sea Eagle in north-west Kazakhstan in 1990-2002.Pp. 551-556. *In:* Chancellor, R. D. & B.-U. Meyburg eds. Raptors Worldwide: Proceedings of the WWGBP - 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.
4. Sklyarenko, S.L., **T. Katzner**, M. McGrady. 2003. Population status of scavenger raptors in south-eastern Kazakhstan. [in Russian]. Materials of the 4th Conference on Raptors of Northern Eurasia. Penza, Russia.
3. Sklyarenko, S.L., M. McGrady, **T. Katzner**, and A.V. Kovalenko. 2003. Group nesting of Black Vultures in Kazakhstan [in Russian]. Materials of the 4th Conference on Raptors of Northern Eurasia. Penza, Russia.
2. Katzner, T.,and S. Sklyarenko. 2002. Conservation status of griffon and other vultures in central Asia. North American Ornithological Congress, New Orleans, LA. *In:* Katzner, T., and J. Parry-Jones. 2003. Reports of the Workshop Conservation of *Gyps* vultures in Asia. North American Ornithological Conference, New Orleans, LA, 2002.
1. Parker, K.L. and **T.E. Katzner.** 1993. Evaluating shrub-steppe habitat quality using the pygmy rabbit (*Brachylaygus idahoensis*) as an indicator species. Pp. 43-51. *In*: H.J. Harlow and M. Harlow, *eds.*, University of Wyoming National Park Service Research Center, 17th Annual Report. Laramie, WY.

PAPERS PRESENTED, WORKSHOPS ATTENDED & SESSIONS ORGAINZED OR CHAIRED

106. Kapetanakos, Y., **T. Katzner**, & I. Lovette. 2012. Filling in the gaps: using non-invasive genetic mark-recapture to develop a comprehensive demographic assessment of critically endangered vultures in Cambodia. North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.
105. Miller, T., R. Brooks, **T. Katzner**, M. Lanzone, C. Maisonneuve, J. Tremblay, J. Cooper & K. O'Malley. 2012. Seasonal and intraspecific drivers of movement ecology of a migratory avian predator. North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.
104. Duerr, A.E., T. Miller, M. Lanzone, D. Brandes, J. Cooper, K. O'Malley, C. Maisonneuve, J. Tremblay & **T.Katzner**. 2012. Weather drives migratory flight behavior of golden eagles: implications for understanding wind-wildlife interactions and climate change effects oKn migratory behavior. North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.
103. Katzner, T., D. Brandes, T. Miller, M. Lanzone, C. Maisonneuve, J. Tremblay, B. Mulvihill & G. Merovitch. 2012. Topography drives migratory flight altitude of golden eagles: implications for wind energy development. North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

102. Wheeler, M., **T. Katzner** & B. Porter. 2012. Assessing the genetic diversity and distinctiveness of eastern North American golden eagles: long-term conservation impacts of exotic introductions on a small native population. North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.

101. Tremblay, J. C. Maisonneuve, **T. Katzner**, T. Miller, M. Lanzone, D. Brandes. 2012. A case study of the interaction between landscape configuration and habitat use at a wind facility by golden eagles (*Aquila chrysaetos*). North American Ornithological Conference, Vancouver, BC, 14-18 August 2012.

100. Workshop Organizer: Eastern Golden Eagle Working Group, Second Meeting. Sainte-Anne-des-Monts, Quebec, Canada, 10-13 July 2012.

99. Брагин Е.А., **Катцнер Т.**, Брагин А.Е. 2012. Пространственные связи популяции орла-могильника *Aquila heliaca* островных лесов Костанайской области [The spatial relations of the Imperial Eagle Aquila heliaca population of forest patches of Kostanay Region]. Second international conference on biodiversity of Asian steppes. Kostanay, Kazakhstan, 5-6 June 2012.

98. Katzner, T.E. J.A.R. Ivy, E.A. Bragin, E.J. Milner-Gulland & J.A. DeWoody. 2012. How many eagles are at Naurzum? Second international conference on biodiversity of Asian steppes. Kostanay, Kazakhstan, 5-6 June 2012. *Plenary session.*

97. Katzner, T.E, D. Brandes, T.A. Miller, M. Lanzone, C. Maisonneuve, J.Tremblay, R. Mulvihill & G. Merovich. 2012. Topography drives migratory flight altitude of golden eagles: implications for on-shore wind energy development. Northeastern Association of Fish and Wildlife Agencies Annual Meeting, Charleston, WV.

96. Katzner, T., B.W. Smith, T. A. Miller, D. Brandes, J. Cooper, M. Lanzone, D. Brauning, C. Farmer, S. Harding, D. Kramar, C. Koppie, C. Maisonneuve, M. Martell, E..K. Mojica, C. Todd, J.A. Tremblay, M. Wheeler, D.F. Brinker, T.E. Chubbs, R. Gubler, K. O'Malley, S. Mehus, B. Porter, R.P. Brooks, B.D. Watts & K.L. Bildstein. 2012. Status, biology and conservation priorities for North America's eastern Golden Eagle (*Aquila chrysaetos*) population. Northeastern Association of Fish and Wildlife Agencies Annual Meeting, Charleston, WV.

95. Miller, T.A., M. Lanzone, R.P. Brooks, J. Cooper, P.J. Turk, **T.E. Katzner**, C. Maisonneuve & J.A. Tremblay. 2012. Seasonal variation in home range size and movement patterns of golden eagles (*Aquila chrysaetos*) in eastern North America. Northeastern Association of Fish and Wildlife Agencies Annual Meeting, Charleston, WV.

94. Duerr, A.E., T.A. Miller, M. Lanzone, D. Brandes, K. O'Malley, C. Maisonneuve, J. Tremblay & **T. Katzner**. 2012. Flight speed during migration: is using slope soaring faster than gliding between thermals? Northeastern Association of Fish and Wildlife Agencies Annual Meeting, Charleston, WV.

93. Sklyarenko, S. & **T. Katzner.** 2011. Status of populations of vultures in Kazakhstan. International ornithological conference devoted to centerary of birth of M.N. Korelov, Almaty, Kazakhstan. [In Russian, given as Состояние популяций хищных птиц-падальщиков в Казахстане. Международная орнитологическая конференция, посвященная 100-летию со дня рождения М.Н. Корелова].

92. Participant: American Wind Wildlife Institute, Eagle Workshop. 2011. Hosted by USFWS Mountain and Prarie Office, Region 6, Denver, Colorado, USA.

91. Katzner, T., T. Miller, D. Brandes, J. Cooper, A. Duerr, M. Lanzone, C. Maisonneuve, J. Tremblay, R. Brooks, P. Turk & K. O'Malley. 2011. High frequency GPS telemetry to evaluate migration and habitat use of raptors relative to wind development. The Wildlife Society's 18th Annual Conference, Kona, Hawaii.

90. Katzner, T., B.W. Smith, T. A. Miller, D. Brandes, J. Cooper, M. Lanzone, D. Brauning, C. Farmer, S. Harding, D. Kramar, C. Koppie, C. Maisonneuve, M. Martell, E..K. Mojica, C. Todd, J.A. Tremblay, M. Wheeler, D.F. Brinker, T.E. Chubbs, R. Gubler, K. O'Malley, S. Mehus, B. Porter, R.P. Brooks, B.D. Watts & K.L. Bildstein. 2011. Status, biology and conservation priorities for North America's eastern Golden Eagle (*Aquila chrysaetos*) population. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

89. Maisonneuve, C., J. Tremblay, T. Miller, **T. Katzner**, M. Lanzone, D. Brandes. 2011. Variation in home range sizes of golden eagles (*Aquila chrysaetos canadensis*) breeding in Quebec. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

88. Miller, T., M. Lanzone, D. Brandes, C. Maisonneuve, J. Cooper, K. O'Malley, R. Brooks & **T. Katzner**. 2011. Characteristics of spring migration of golden eagles (*Aquila chrysaetos*) through eastern North America, as determined by GPS-GSM and conventional satellite telemetry. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

87. Miller, T., M. Lanzone, **T. Katzner**, P. Turk, D. Brandes. C. Maissoneuve, J. Tremblay, J. Cooper. K. O'Malley & R.P. Brooks. 2011. Striking a balance: Modeling migration of golden eagles (*Aquila chrysaetos*) through wind energy developments of the Central Appalachian Mountains, USA. Raptor Research Foundation 2011 Annual Meeting, Duluth, MN. *Student presentation award winner.*

86. Brandes, D., C. Maisonneuve, J. Tremblay, T. Miller, **T. Katzner**, & M. Lanzone. 2011. Influence of high-latitude warming on fall migration timing of eastern golden eagles (*Aquila chrysaetos*). Raptor Research Foundation 2011 Annual Meeting, Duluth, MN.

85. Cooper, J., T. Miller, **T. Katzner**, M. Lanzone, D. Kramar, K. O'Malley, C. Maisonneuve, & J. Tremblay. 2011. Winter ranging behavior of golden eagles (*Aquila chrysaetos*) in the central Appalachian Mountains. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

84. Wheeler, M., B. Porter & **T. Katzner**. 2011. Assessing the genetic diversity and distinctness of eastern North American golden eagles. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

83. Duerr, A., T. Miller, M. Lanzone, J. Cooper, P. Turk & **T. Katzner**. 2011. High frequency GPS-GSM telemetry to measure migration speed: do golden eagles migrate faster when using orographic or thermal lift? Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

82. Lanzone, M., C. Halverson, T. Miller, P. Turk, D. Brandes & **T. Katzner**. 2011. High-frequency GPS-GSM telemetry provides new insights into raptor behavior and ecology. Raptor Research Foundation 2011 Annual Meeting, Duluth ,MN.

81. Session chair: Conservation of Vultures Around the World**.** Workshop on the future of vultures in Israel and the Middle East. 19-22 September, Kfar Blum, Hula Valley, Israel.

80. Katzner, T. Y. Kapetanakos, I. Lovette, S. Sklyarenko, H. Rainy & B. Pech. 2011. Non-invasive monitoring to estimate demography of vultures in central & south Asia. Workshop on the future of vultures in Israel and the Middle East. 19-22 September, Kfar Blum, Hula Valley, Israel.

79. Miller, T., M. Lanzone, P. Turk, D. Brandes. C. Maissoneuve, J. Tremblay, J. Cooper. K. O'Malley. **T. Katzner**, R.P. Brooks. 2011. Striking a balance: Modeling migration of golden eagles (*Aquila chrysaetos*) through wind energy developments of the Central Appalachian Mountains, USA. Spatial Ecology and Conservation Conference, Birmingham, UK.

78. Katzner, T., T. Miller, M. Lanzone, D. Brandes, R. Brooks, J. Cooper, C. Maisonneuve, J. Tremblay, K. O'Malley. 2010. Golden Eagles and Wind Energy in Eastern North America. U.S. Fish and Wildlife Service, Northeast Region Biologists Conference, 15-18 Feb, Baltimore, MD.

77. Katzner, T. 2010. Demography of eastern golden eagles: population estimation for the past and present. Hawk Mountain Sanctuary, Kempton, PA.

76. Workshop Organizer: Eastern Golden Eagle Working Group, First Meeting. Hawk Mountain Sanctuary, 17-19 November 2010, Kempton, PA.

75. Katzner, T., T. Miller, M. Lanzone, D. Brandes, R. Brooks, J. Cooper, C. Maisonneuve, J. Tremblay, K. O'Malley. 2010. Interactions between migratory birds of prey and wind turbines: insights from novel high frequency gps-gsm telemetry. NWCC Wind Wildlife Research Meeting, Denver, CO.

74. Tremblay, J., C. Maisonneuve. **T. Katzner**, T. Miller, M. Lanzone, & D. Brandes. 2010. A case study of the interaction between landscape configuration and visits of a wind facility by Golden Eagles (*Aquila chrysaetos*). NWCC Wind Wildlife Research Meeting, Denver, CO.

73. Maisonneuve, C., J. Tremblay, **T. Katzner**, T. Miller, M. Lanzone & D. Brandes. 2010. Influence of landscape configuration on wind facility frequentation by Golden eagles - A case study. Raptor Research Foundation Annual Meeting, Ft. Collins, CO.

72. Katzner, T. T. Miller, M. Lanzone, D. Brandes, & R. Brooks. 2010. Threats to migrating raptors from development of wind energy: Golden eagles as an umbrella species for conservation. Ecological Society of America, Annual Conference, Pittsburgh, PA.

71. Session Moderator: Movement and Migration. The 6th International Conference on Asian Raptors, ARRCN. Ulaanbaatar, Mongolia.

70. Katzner, T. 2010. Marking and tracking methods for birds of prey: why do it and what options are available. The 6th International Conference on Asian Raptors, ARRCN. Ulaanbaatar, Mongolia.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

69. Katzner, T., T. Anderson, T. Miller & M. Lanzone. 2010. High frequency gps-gsm telemetry for study of movement ecology of raptors. The 6th International Conference on Asian Raptors, ARRCN. Ulaanbaatar, Mongolia.

68. Katzner, T., T. Miller, M. Lanzone, D. Brandes, & R. Brooks. 2010. Threats to migrating golden eagles from development of wind energy. Wilson Ornithological Society 2010 Annual Meeting, Geneva, NY.

67. Brandes, D., G. Bohrer, J. Mandel, **T. Katzner**, T. Miller, M. Lanzone, C. Maisonneuve, and J. Tremblay. 2010. Raptor migration by computer – using modeling and satellite tracking data to fill in the gaps. 2010 Conference of the Hawk Migration Association of North America, Duluth, MN.

66. Anderson, T., C. Halverson, **T. Katzner**, M. Lanzone & T. Miller. 2010. High frequency GPS-GSM telemetry data to delineate flight strategies of migratory birds: an example with golden eagles. Bird Migration and Global Change: Second Conference. Algeciras, Spain.

65. Session Moderator: Eagle population monitoring and field research. 2009. Third Annual Conference of the Eagle Conservation Alliance, Ainsa, Spain.

64. Miller, T., D. Brandes, M. Lanzone, D. Ombalski, C. Maisonneuve, R.P. Brooks and **T. Katzner**. 2009. Flight behavior of migrating golden eagles in the eastern USA: insights from high-frequency telemetry. Third Annual Conference of the Eagle Conservation Alliance, Ainsa, Spain.

63. Lanzone, M., C. Halverson and **T. Katzner**. 2009. High frequency GSM telemetry for tracking eagles. Third Annual Conference of the Eagle Conservation Alliance, Ainsa, Spain.

62. Session Moderator: General Session. Raptor Research Foundation 2009 Annual Conference, Pitlochry, Scotland.

61. Brandes, D., **T. Katzner**, T. Miller and M. Lanzone. 2009. Simulation of golden eagle (*Aquila chrysaetos*) migration pathways through the central Appalachians. Raptor Research Foundation 2009 Annual Conference, Pitlochry, Scotland.

60. Miller, T., D. Brandes, M. Lanzone, D. Ombalski, C. Maisonneuve, R.P. Brooks and **T. Katzner**. 2009. Modeling migratory flight characteristics of eastern North American golden eagles (*Aquila chrysaetos*) using high-frequency telemetry data. Raptor Research Foundation 2009 Annual Conference, Pitlochry, Scotland.

59. Lanzone, M., C. Halverson and **T. Katzner**. 2009. Development of a high-frequency GSM telemetry device for tracking raptors. Raptor Research Foundation. 2009 Annual Conference, Pitlochry, Scotland.

58. Jackson, D.S., J.A.R.Ivy, E.A. Bragin, A. DeWoody & **T. Katzner**. 2009. Variation in offspring sex ratio of the sexually dimorphic, long-lived eastern imperial eagle. Raptor Research Foundation 2009 Annual Conference, Pitlochry, Scotland.

57. Miller, T., M. Lanzone, C. Maisonneuve, A. Mack, R.P. Brooks and **T. Katzner**. 2009. Multi-scale application of a common hydrological measure to migratory flight paths obtained from satellite and high frequency GSM telemetry. American Ornithologists Union, Philadelphia, PA.

56. Participant: "Scaling biodiversity monitoring from the local to the global." 2009. Hosted by Centre for Population Biology, Imperial College London. Ascot, UK.

55. Kapetanakos, Y. and **T. Katzner**. 2009. DNA barcoding is for the birds: using an old technique in new situations: a case study for Asian vultures. Wilson Ornithological Society & Association of Field Ornithologists, 2009 Joint Annual Conference, Pittsburgh, PA. 2006-2009.

54. Miller, T., M. Lanzone, R. Brooks and **T. Katzner**. 2009. Flight characteristics of golden eagles (*Aquila chrysaetos*) migrating through eastern North America as determined by GPS telemetry. Wilson Ornithological Society & Association of Field Ornithologists, 2009 Joint Annual Conference, Pittsburgh, PA. 2006-2009.

53. Lanzone, M., C. Halverson, and **T. Katzner.** 2009. A high frequency GSM telemetry device for tracking wildlife. Wilson Ornithological Society & Association of Field Ornithologists, 2009 Joint Annual Conference, Pittsburgh, PA. 2006-2009.

52. Maisonneuve, C., T.A. Miller, M.J. Lanzone, and **T.E. Katzner**. 2008. Studies on threatened species of birds of prey and wind farms in eastern North America. Nature and Biodiversity Conservation Union. International Workshop on Birds of Prey and Wind Farms. Berlin, Germany.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

51. Miller, T.A., C. Maisonneuve and **T.E. Katzner** 2008. Determining where, in eastern North America, there is the greatest potential for conflict between Golden Eagles and wind power development. Wind Wildlife Research Meeting VII. Milwaukee, WI.

50. Katzner, T.E., J. Ibaňez, N. Collar. 2008. Ecology and conservation status of the Philippine eagle: a species in need of landscape scale conservation. Setting landscape conservation targets and promoting them through compatible land use in the Philippines. Conservation International (CI) and World Agroforestry Centre (ICRAF) Philippines Project Meeting, Los Baňos, Philippines.

49. Participant: Setting landscape conservation targets and promoting them through compatible land use in the Philippines. 2008. Conservation International (CI) and World Agroforestry Centre (ICRAF) Philippines Project Meeting, Los Baňos, Philippines.

48. Participant: Defying Extinction: Philippine Eagle Action Plan National Workshop" 2008. Tagaytay, Philippines. Co-hosted by Philippines Protected Areas and Wildlife Bureau and the Philippine Eagle Foundation.

47. Bragin, E.A., J. Rudnik, **T. Katzner**, A. DeWoody. 2008. New methods for raptors research: results of research on the imperial eagle in north Kazakhstan. 5th international conference on birds of prey of northern Eurasia. Ivanovo, Russia.

46. Bragin, A., **T. Katzner**, P. Sharpe, D. Garcelon, A. E. Bragin. 2008. Results of research on imperial eagle migrations from northern Kazakhstan. 5th international conference on birds of prey of northern Eurasia. Ivanovo, Russia.

45. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2007. A noninvasive genetic evaluation of population size and natal philopatry of non-breeding eastern imperial eagles (*Aquila heliaca*) in Kazakhstan. Conservation Genetics Symposium, New York, NY.

44. Session Moderator: Sampling and Techniques. 2007 Joint Conference of the Raptor Research Foundation and the Hawk Migration Association of North America, Fogelsville, PA.

43. Brandes, D., **T. Katzner**, T. Miller, M. Lanzone, K. Bildstein and D. Ombalski. 2007. A terrain-based dynamic model for simulating raptor migration through the Appalachians. 2007 Joint Conference of the Raptor Research Foundation and the Hawk Migration Association of North America, Fogelsville, PA.

42. Miller, T., D. Brandes, M. Lanzone, D. Ombalski, R. Mulvihill, R. Brooks and **T. Katzner**. 2007. Flight characteristics of golden eagles (*Aquila chrysaetos*) migrating through eastern North America as determined by GPS telemetry. 2007 Joint Conference of the Raptor Research Foundation and the Hawk Migration Association of North America, Fogelsville, PA.

41. Lanzone, M., T. Miller, D. Brandes, D. Ombalski, R. Mulvihill and **T. Katzner**. 2007. Golden eagle (*Aquila chrysaetos*) wintering behavior in the Appalachian Mountains of eastern North America using GPS satellite telemetry. 2007 Joint Conference of the Raptor Research Foundation and the Hawk Migration Association of North America, Fogelsville, PA.

40. Katzner, T.E., J. Rudnick, E.A. Bragin and J.A. DeWoody. 2007. What you see isn't always what you get: how accurate are counts of raptors and how many non-breeders are really out there? 2007 Joint Conference of the Raptor Research Foundation and the Hawk Migration Association of North America, Fogelsville, PA.

39. Katzner, T.E., J. Rudnick, E.A. Bragin, J.A. DeWoody and E.J. Milner-Gulland. 2007. New approaches to monitoring eagles: collecting the most appropriate data & doing it without disturbing the birds. 2nd Annual meeting of the Eagle Conservation Alliance. Puebla, Mexico.

38. Katzner, T., E.J. Milner-Gulland and E. Bragin. 2007. Using modeling to improve monitoring of eagles: are we collecting the right data? International Scientific Conference "Biological Diversity of Asian Steppe," Kostanay, Kazakhstan.

37. Terraube, J., B. Arroyo, F. Mougeot and **T. Katzner.** 2006. Reproductive and trophic ecology of Pallid Harriers in north Kazakhstan: implications for population dynamics and conservation. 9th Congress on Spanish Harriers. Castuera, Extramadura, Spain.

36. Sklyarenko, S. and **T. Katzner**. 2006. Status and distribution of black vulture, Eurasian griffon vulture and Himalayan griffon vulture in central Asia. Conference on Ornithological Research in Northern Eurasia. Stavropol, Russia.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

35. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2005. A Noninvasive Investigation of Juvenile Population Size and Natal Philopatry in the Eastern Imperial Eagle. Conservation Genetics Symposium, Pacific Grove, CA.

34. Poulakakis, N., Mantziou, G., Antoniou, A., Parmakelis, A., Skartsi, T., Vasilakis, D., Elorriaga, J., de la Puente, J., Gavashelishvili, A., Ghasabian, M, **Katzner, T.**, McGrady, M. Batbayar, N., Fuller, M, and Natsagdorj, T. 2005 Using microsatellite markers to infer the genetic structure of *Aegypius monachus* (Aves:Accipitridae). International Conference on Conservation and Management of Vulture Populations, Thessaloniki, Greece.

33. Katzner, T., E.J. Milner-Gulland and E. Bragin. 2005. Using modeling to improve monitoring of birds: are we collecting the right data? Wilson Ornithological Society - Association of Field Ornithologists 2005 Joint Meeting. Beltsville, MD.

32. Rudnick, J. **T. Katzner**, O.E. Rhodes, Jr., J.A. DeWoody. 2004.Non-invasive Monitoring of an Eastern Imperial Eagle Population in Kazakhstan. Society for Conservation Biology Conference, New York, NY.

31. Galushin, V., **T. Katzner** and S. Sklyarenko. 2004. The black vulture in Russia and Kazakhstan. International Symposium on the Black Vulture *Aegypius monachus*. Cordoba, Spain.

30. Katzner, T., E. Bragin, E.J. Milner-Gulland. 2004. Using modelling to improve monitoring of raptors in forest-steppe: an example with Imperial Eagles (*Aquila heliaca*) in Kazakhstan. International Symposium on Ecology and Conservation of Steppe-Land Birds, Lleida, Spain.

29. Rudnick, J. **T. Katzner**, O.E. Rhodes, Jr., J.A. DeWoody. 2004. Non-invasive monitoring of an Imperial Eagle population in Kazakhstan. 2004 Meeting of the Indiana Chapter of The Wildlife Society, Bloomington, IN, U.S.A. *Poster presentation.*

28. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2004. Non-invasive Monitoring of an Eastern Imperial Eagle Population in Kazakhstan. Midwest Fish and Wildlife Conference Indianapolis, IN.

27. Katzner, T., A. Gavashelishivili, S. Sklyarenko, M. McGrady, J. Shergalin, and K. Bildstein. 2003. Population and conservation status of Griffon Vultures in the former Soviet Union. 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.

26. Bragin, E.A. and **T. Katzner**. 2003. Population trends and nesting success of Imperial, Golden and White-tailed Sea Eagles in North-west Kazakhstan. 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.

25. Katzner, T., E. Bragin, S. Knick, and A. Smith. 2003. Dietary response and demography of Imperial Eagles (*Aquila heliaca*) in a spatially heterogeneous environment in Kazakhstan. 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.

24. Rudnick, J.A., **T.E. Katzner**, E.A. Bragin, and J.A. DeWoody. 2003. The Effective Population Size and Mating System of an Eastern Imperial Eagle Population in Kazakhstan. Joint Meeting of the Indiana Chapters of The Wildlife Society and The American Fisheries Society, Bloomington, IN. *Poster presentation.*

23. Session Chair: Old world Vulture Studies: Population status and movements. 6th World Conference on Birds of Prey and Owls, Budapest, Hungary.

22. Sklyarenko, S.L., **T. Katzner**, M. McGrady. 2003. Population status of scavenger raptors in south-eastern Kazakhstan. [in Russian]. 4th Conference on Raptors of Northern Eurasia. Penza, Russia.

21. Sklyarenko, S.L., M. McGrady, **T. Katzner**, and A.V. Kovalenko. 2003. Group nesting of Black Vultures in Kazakhstan [in Russian]. 4th Conference on Raptors of Northern Eurasia. Penza, Russia.

20. Katzner, T., E. Bragin, S. Knick and A. Smith. 2002. Dietary response and demography in a population of imperial eagles in a spatially heterogeneous environment in Kazakhstan. North American Ornithological Congress, New Orleans, LA. *Received student presentation award.*

19. Katzner, T., S. Sklyarenko, A. Gavashelishvili, M. McGrady and K. Bildstein. 2002. Abundance and conservation status of vultures in the former Soviet Union. North American Ornithological Congress, New Orleans, LA. *Poster presentation.*

18. Co-organizer: (with Jemima Parry-Jones), Workshop AConservation of *Gyps* vultures in Asia.@ North American Ornithological Congress, New Orleans, LA, September 2002.

PAPERS PRESENTED, WORKSHOPS ATTENDED &SESSIONS ORGAINZED OR CHAIRED (cont.)

17. Busch, J., **T. Katzner**, E. Bragin and P. Keim. 2002. Development of polymorphic microsatellite markers that amplify across two eagle genera. North American Ornithological Congress, New Orleans, LA. *Poster presentation.*

16. Katzner, T.,and S. Sklyarenko. 2002. Conservation status of griffon and other vultures in central Asia. North American Ornithological Congress, New Orleans, LA. *Workshop presentation.*

15. Katzner, T., S. Knick, E. Bragin and A. Smith. 2002. The role of intraspecific interactions in the coexistence of four species of eagles at a nature reserve in Kazakhstan. International Ornithological Congress, Beijing, China.

14. Rudnick, J., **Katzner, T**., Busch, J., Rhodes, O.E. and J.A. DeWoody. 2002. Genetic variation and parentage in three species of Eurasian eagles. The 2002 Joint Meeting of the Indiana Chapters of The Wildlife Society and The American Fisheries Society, Bloomington, IN, U.S.A. *Poster presentation*.

13. Rudnick, J., **Katzner, T**., Busch, J., Rhodes, O.E. and J.A. DeWoody. 2002. Genetic variation and parentage in three species of Eurasian eagles. The 2002 Midwest Ecology and Evolution Conference, Bowling Green, OH, U.S.A. *Poster presentation*.

12. Participant: Regional meeting on the conservation of pygmy rabbits in Washington, Washington Department of Fish and Wildlife, 2002.

11. Katzner, T., Knick, S., Bragin, E., and A. Smith. 2001. The role of intraspecific interactions in the coexistence of four species of eagles at a nature reserve in Kazakhstan. 4th Eurasian Congress on Raptors, Sevilla Spain.

10. Co-organizer: (with Jemima Parry-Jones), Workshop: Indian griffon vultures and their problems. 4th Eurasian Congress on Raptors, Seville, Spain, September 2001.

9. Participant: International Workshop on Red Listing. IUCN/SSC, INTAS, and the Uzbek Academy of Sciences, sponsors. Gazalkent, Uzbekistan, September 2001.

8. Katzner, T., Knick, S., Bragin, E., and A. Smith. 2001. Species Coexistence Mediated by Intraspecific Interactions: Evidence from a Unique Community of Eagles in Central Asia. 2001 Annual Meeting, Cooper Ornithological Society, Albuquerque, NM, U.S.A.

7. Katzner, T.E. and S.L. Sklyarenko. 2000. Status of Vulture Populations in a Region of South-eastern Kazakhstan. 2000 Annual Meeting, Raptor Research Society, Jonesboro, AR, U.S.A. *Poster presentation.*

6. Katzner, T.E., S.T. Knick, E.A. Bragin, D.W. Katzner and A.T. Smith. 1999. Understanding relationships among raptors: alternative numerical and graphical approaches to diet analysis. 1999 Annual Meeting, Raptor Research Foundation, La Paz, Mexico.

5. Katzner, T.E., S.T. Knick, E.A. Bragin, D.W. Katzner and A.T. Smith. 1999. Alternative approaches to analysis of diets of raptors. 3rd Eurasian Conference of the Raptor Research Foundation, Mikulov na Morav., The Czech Republic.

4. Knick, S.T., T.M. Bragina, E.A. Bragin, and **T.E. Katzner.** 1999. Habitat mapping from satellite imagery in Kazakstan. 2nd International Wildlife Management Conference, Gödöllö, Hungary. *Poster presentation.*

3. Katzner, T.E., E.A. Bragin, S.T. Knick and A.T. Smith. 1998. Nest spacing and diet selection in a unique multi-species community of eagles in central Asia. 1998 Annual Meeting, Raptor Research Foundation, Ogden, Utah, U.S.A.

2. Katzner, T.E. and K.L. Parker. 1994. Winter ecology of the pygmy rabbit in Wyoming. Wyoming Chapter of the Wildlife Society Meeting, Casper, WY, U.S.A.

1. Katzner, T.E. and Y.P. Cruz. 1991. Interspecific competition between an ecto- and an endoparasitoid of the larvae of the moth *Anagasta keuhniella*. NCB Entomological Society of America Meeting, Milwaukee, WI, U.S.A. *Poster presentation.*

INVITED SYMPOSIA

57. Katzner, T.E. 2012. Golden eagles & wind energy in eastern North America: new threats along historical migration routes. Eastern Massachusetts Hawkwatch Annual Meeting Plenary Speaker, Bedford, MA.

56. Katzner, T.E. 2012. Golden eagles & wind energy in eastern North America: new threats along historical migration routes. Sharon Audubon Society, Sharon, CT.

55. Katzner, T.E. 2012. Understanding Movement Ecology and Risk Assessment for Golden Eagles and Wind Energy in Eastern North America. Department of Biology, University of Pittsburgh, Pittsburgh, PA.

54. Katzner, T.E. 2012. Status and ecology of the golden eagle in West Virginia. 55th Annual Joint Reservoir Management Meeting. Chief Logan State Park, WV.

53. Katzner, T.E. 2011. Golden eagles & wind energy in eastern North America: new threats along historical migration routes. USFWS Science Seminar Series, USFWS Region 5 regional offices, Hadley, MA.

52. Katzner, T.E. 2011. West Virginia's Golden Eagles and Wind Energy: new threats along historical migration routes. Mountaineer Audubon Society, Morgantown, WV.

51. Katzner, T. 2011. Status, conservation and demography of eastern golden eagles in West Virginia. WVDNR-USFS Stamps Meeting, Blackwater State Park, Davis, WV.

50. Katzner, T. 2011. Non-invasive demography of central Asian eagles. WVU – International Research Symposium, Morgantown, WV.

49. Katzner, T.E. 2011. Conservation and Ecology of Eagles around the World. Three Rivers Bird Club, Pittsburgh, PA.

48. Miller, T.M., M. Lanzone, D. Brandes, **T. Katzner.** 2011. Golden Eagle Research Project. Pennsylvania Society for Ornithology. Annual Meeting, Bedford, PA.

47. Katzner, T.E. 2011. West Virginia's Golden Eagles and Wind Energy: new threats along historical migration routes. Maurice Brooks Lecture, Morgantown WV.

46. Katzner, T.E. 2011. Conservation and Ecology of Eagles around the World. The Wildlife Society, WVU Student Chapter, Morgantown, WV.

45. Katzner, T.E. 2011. Asian vulture decline: addressing the world's greatest modern ornithological conservation catastrophe. Linn County Community Connections Speaker, Cedar Rapids, IA.

44. Katzner, T.E. 2011. Golden Eagles and Wind Energy in Eastern North America. Coe College Department of Biology, Cedar Rapids, IA.

43. Katzner, T.E. 2011. Conservation and Ecology of Eagles around the World. International Association of Avian Trainers and Educators, Annual Conference, Pittsburgh, PA, 17 Feb 2011. *Keynote address.*

42. Katzner, T.E. 2011. Asian vulture decline: addressing the world's greatest modern ornithological conservation catastrophe. Wildlife & Fisheries Seminiar, Division of Forestry & Natural Resources, West Virginia University, Morgantown, WV.

41. Katzner, T.E. 2010. Golden eagles and wind energy: siting wind power for improved conservation management. Delaware Valley Ornithological Club, Philadelphia, PA.

40. Katzner, T.E. 2010. Golden eagles and energy development in the central Appalachians: application of novel high frequency GSM telemetry for predictive modeling. US Forest Service, Parsons, WV.

39. Katzner, T.E. 2010. Developing best practices for siting wind turbines: utility grade wind energy and soaring birds of prey. Pennsylvania Game Commission, Wind Energy Cooperator's Meeting, Harrisburg, PA.

38. Katzner, T.E. 2010. Eagle conservation ecology across two continents. West Virginia University Division of Forestry and Natural Resources, Morgantown, WV.

37. Katzner, T.E. 2010. Non-invasive approaches to demography of rare and endangered species. Smithsonian Conservation Biology Institute, Front Royal, VA.

36. Katzner, T.E. 2010. Non-invasive approaches to demography of rare and endangered species. Department of Biology, Indiana University of Pennsylvania, Indiana, PA.

35. Maisonneuve, C., J. A. Tremblay, T. Miller, D. Brandes, M. Lanzone, and **T. Katzner**. 2009. L'utilisation de la télémétrie satellitaire pour intégrer les besoins des oiseaux de proie dans le développement éolien. (The use of satellite telemetry to integrate the needs of birds of prey in the wind energy development) University of Québec at Rimouski.

34. Katzner, T.E. 2009. Eagles and Vultures in Asia: Non-invasive demography of threatened & endangered species. Birding and Ornithology Club, University of Pittsburgh, Pittsburgh, PA.

33. Katzner, T.E., Y. Kapetanakos, I. Lovette, S. Sklyarenko & N. Clum. 2009. Asian vulture decline: addressing the world's greatest modern ornithological conservation catastrophe. Delaware – Otsego Audubon Society, Oneonta, NY.

INVITED SYMPOSIA (cont.)

32. Katzner, T.E. 2009. Non-invasive demography of threatened & endangered vultures and eagles. Department of Biology, Hartwick College, Oneonta, NY.

31. Katzner, T.E., D. Brandes, M. Lanzone, C. Maisonneuve, T. Miller and D. Ombalski. 2009. Migrating eagles and wind turbines: filling the information void. Biology Department, State University of New York, College at Oneonta, Oneonta, NY.

30. Katzner, T.E., D. Brandes, M. Lanzone, C. Maisonneuve, T. Miller and D. Ombalski. 2009. Sustainable energy and wildlife: research for coexistence. Sigma Xi Society, Alcoa Inc., Chapter.

29. Katzner, T.E., D. Brandes, M. Lanzone, C. Maisonneuve, T. Miller and D. Ombalski. 2009. Eagles and falcons in Pennsylvania: research and natural history for conservation. Point Park University, Pittsburgh PA.

28. Katzner, T.E. 2009. Migrating Eagles and Wind Turbines: Filling the Information Void. The Pennsylvania State University, New Kensington Campus.

27. Brandes, D., **Katzner, T.,** Miller, T., Lanzone, M., and D. Ombalski. 2009. Appalachian wind energy and raptors: moving forward in a data vacuum. Appalachian Laboratory, University of Maryland Center for Environmental Science.

26. Katzner, T.E. 2008. Migrating Eagles and Wind Turbines: Filling the Information Void. Hawk Mountain Sanctuary Association, Kempton, PA.

25. Katzner, T.E. 2008. Counting accurately from afar: non-invasive approaches to demography of rare and endangered species. The University of Pittsburgh Pymatuning Laboratory of Ecology, Linesville, PA

24. Katzner, T.E. 2008. Migrating Eagles and Wind Turbines: Conflict Potential in an Information Void. Pennsylvania Society of Ornithology Annual Meeting, Pittsburgh, PA.

23. Katzner, T.E. 2008. Human population density: impacts on biodiversity. Lessons from a cross continental evaluation. Invited Plenary Speaker, Wildlife Conservation Society of the Philippines, Baybay City, Philippines.

22. Katzner, T.E. 2008. Migrating Eagles and Wind Turbines: Resolving Conflict in an Information Void. University of Pittsburgh, Honors College, Pittsburgh, PA.

21. Katzner, T.E. 2008.Research and conservation medicine: present and future perspectives from a field biologist. University of Pennsylvania, College of Veterinary Medicine, Philadelphia, PA.

20. Katzner, T.E. 2008. Non-invasive sample collection provides new insight to demographics of rare and endangered species. National Museum of the Philippines, Manila, Philippines.

19. Katzner, T.E. 2008. Conservation ecology at arm's length: non-invasive approaches to demography of rare and endangered species. Department of Biology, University of the Philippines – Diliman, Manila, Philippines.

18. Katzner, T.E. 2007. Conservation ecology at arm's length: non-invasive approaches to demography of rare and endangered species. Department of Biology, Westminster College, New Wilmington PA.

17. Katzner, T.E. 2007. Conservation ecology at arm's length: non-invasive approaches to demography of rare and endangered species. Odum School of Ecology, University of Georgia, Athens, GA.

16. Katzner, T.E. 2006. Non-invasive population studies of threatened raptors. Pennsylvania Society of Ornithology Annual Meeting, Powdermill Nature Reserve, PA.

15. Katzner, T.E. 2006. Conservation ecology at arm's length: non-invasive demography of rare and endangered species. Department of Biological Sciences. Duquesne University, Pittsburgh, PA.

14. Katzner, T.E. 2005. Ecology and conservation of eagles and vultures in central Asia: non-invasive approaches to the study of rare and endangered species. Vermont Institute of Natural Sciences, Queche, VT.

13. Katzner, T.E. 2005. Conservation ecology at arm's length: non-invasive demography of rare and endangered species. Department of Biology Seminar. University of Pittsburgh, Pittsburgh, PA.

12. Katzner, T.E. 2005. Spatial structure in diet of Imperial Eagles (*Aquila heliaca*) in Kazakhstan and its relation to their demography. Coe College Wilderness Field Station, Ely, MN.

11. Katzner, T.E. 2005. Conservation of imperial eagles in Kazakhstan: can we use modeling to assess and improve our monitoring? Ecology & Evolution Seminar. University of Pittsburgh, Pittsburgh, PA.

10. Katzner, T.E. 2004. Does predator diet impact demography? An example from a population of imperial eagles in Kazakhstan. Ecology and Evolution Seminar. Imperial College London at Silwood Park, UK.

9. Katzner, T.E. 2004. Is coexistence of eagles in Kazakhstan mediated by competition? Unidad de Biología Aplicada, Estación Biológica de Doñana, Sevilla, Spain.

INVITED SYMPOSIA (cont.)

8. Katzner, T.E. 2003. Ecology of eagles at the Naurzum Zapovednik, Kazakhstan. Renewable Resources Assessment Group, Department of Environmental Science and Technology, Imperial College, London.

7. Katzner, T.E. 2003. Ecology and behavior of eagles at Naurzum Zapovednik, Kazakhstan. Oberlin College, Department of Biology, Oberlin, OH.

6. Katzner, T.E. 2003. Behavioral ecology of large eagles in Kazakhstan. Acopian Center for Conservation Learning, Hawk Mountain Sanctuary, Orwigsburg, PA.

5. Katzner, T.E. 2003. Eagle ecology and behavior at the Naurzum Nature Reserve, Kazakhstan. Coe College, Department of Biology, Cedar Rapids, IA.

4. Katzner, T.E. 2003. Ecology and conservation of eagles and vultures in Kazakhstan. Wildlife Discussion Group, Purdue University, West Lafayette, IN.

3. Katzner, T.E. 2002. Eagle ecology at a nature reserve in Kazakhstan. Arizona Game and Fish Department, Phoenix, AZ.

2. Katzner, T.E. 2001. Ecology and conservation of eagles and vultures in Kazakhstan. Wildlife Conservation Society, Bronx, NY.

1. Katzner, T.E. and K.L. Parker. 1995. Winter ecology of the pygmy rabbit in Wyoming. Biology Research Seminar, Coe College, Cedar Rapids, IA.

POPULAR PAPERS, PRESENTATIONS, WEB PAGES & PHOTO CREDITS

44. Katzner, T.E. & J. Cooper. 2012. Wild Rebound: A tale of golden eagles. Virginia Widlife. July/August: 22-25.

43. Katzner, T.E. 2012. Conservation ecology of red-footed falcons in Kazakhstan. The Flyer, the newsletter of the International Association of Avian Trainers and Educators. 19(3): 9-10.

42. Katzner, T.E. 2012. Golden eagles & wind energy in the central Appalachians. Rotary Club of Uniontown, PA, 07 February.

41. Katzner, T.E. 2011. Guest speaker. Upward Bound, West Virginia University, Morgantown, WV.

40. Katzner, T.E. 2011**.** Asian vulture decline: addressing the world's greatest modern ornithological conservation catastrophe. Washington High School, Cedar Rapids, IA.

39. Katzner, T.E. 2010. "Flying with eagles: Stories and Book Signing" Carolina Raptor Center. 28 May 2010.

38. Katzner, T.E. 2010. Panelist for "A Rachel Carson Celebration of Biodiversity Honoring E. O. Wilson" Rachel Carson Homestead Association and Carnegie Museum of Natural History. 27 May 2010.

37. Katzner, T.E. 2009. Panelist for "Milking the Rhino" discussion. Carnegie-Mellon University Lecture Series. 16 Nov 2009.

36. Katzner, T.E. 2009. "Too many people?" Lead opinion piece on population growth in Pittsburgh, Sunday Forum Section. Pittsburgh Post-Gazette, 05 July 2009.

35. Katzner, T.E. 2009. Speaker, Great Decisions: The Arctic. World Affairs Council Pittsburgh.

34. Katzner, T.E. 2009. Breakout speaker. Student Ambassador Conference. World Affairs Council Pittsburgh.

33. Ellis, L. and **T. Katzner.** 2009. "Inadvertent Extinction." Connect (AZA Magazine). April 2009.

32. Katzner, T.E. 2008. "From Lead to Dead" Op-ed Page, Pittsburgh Post-Gazette, 19 November 2008.

31. Katzner, T.E. 2008. "Bird Killers" Lead opinion piece on human-caused environmental destruction, Sunday Forum Section, Pittsburgh Post-Gazette, 15 June 2008.

30. Katzner, T.E. 2008. Notes from the field: Bridging the bird gap. Flight Path 2(2):1 & 7 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

29. Katzner, T.E. 2008. Eagles Here and There: Research in Pennsylvania and Kazakhstan. Juniata Valley Audubon Society Annual Banquet, Canoe Creek State Park.

28. Katzner, T.E. 2008. Notes from the Field: Cambodian Vulture Conservation. Flight Path 2(1):1 & 3 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

27. Katzner, T.E. 2008. Partnering for Conservation: Ministère des Ressources Naturelles et de la Faune, Québec, Canada. Flight Path 2(1):5 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

26. Katzner, T.E. 2008. Links across the Aviary: Executive Directions. Flight Path 2(1):7 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

25. Katzner, T.E. 2007. Migrating Eagles and Wind Turbines: Resolving Conflict in an Information Void. Three Rivers Birding Club, Pittsburgh, PA.

POPULAR PAPERS, PRESENTATIONS, WEB PAGES & PHOTO CREDITS (cont.)

24. Katzner, T.E. 2007. Conservation and eagles. Boy Scout Troop 560, Shaler, PA

23. Katzner, T.E. 2007. Conservation ecology at arm's length: non-invasive population studies of threatened raptors. Allegheny Plateau Audubon Society Chapter, Johnstown, PA.

22. Katzner, T.E. 2007. In Rebuttal: Seeing Real Elephants. Op-ed Page, Pittsburgh Post-Gazette, 14 November 2007.

21. Katzner, T.E. 2007. Avian Rehabilitation for Conservation and Science. Flight Path 1(2):1 & 3 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

20. Katzner, T.E. 2007. Partnering for conservation: Sociedad Ornitològica de Hispaniola. Flight Path 1(2):4 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

19. Katzner, T.E. 2007. Human population and biodiversity. Flight Path 1(1):1 & 5 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

18. Katzner, T.E. 2007. Partnering for conservation: Powdermill Avian Research Center. Flight Path 1(1):4 (*Bulletin of the Department of Conservation & Field Research at the National Aviary*).

17. Katzner, T.E. 2006. Avian studies in Kazakhstan: eagles on the edge and vultures on the verge. Sherwood Oaks, Pittsburgh, PA.

16. Katzner, T.E. 2006. 300 million and growing: a complex problem for conservation. Bird Calls 20(3):6. *(National Aviary newsletter)*

15. Katzner, T.E. 2006. Notes from the field..... Bird Calls 20(3):4-5. *(National Aviary newsletter)*

14. Katzner, T.E. 2006. Notes from the field..... Bird Calls 20(2):4-5. *(National Aviary newsletter)*

13. Katzner, T.E. 2006. Notes from the field..... Bird Calls 20(1):2. *(National Aviary newsletter)*

12. Katzner, T.E. 2005. Rotary club breakfast talk. Forest Hills Rotary, Pittsburgh, PA.

11. Katzner, T.E. 2005. Notes from the field..... Bird Calls 19(2):2. *(National Aviary newsletter)*

10. Contributor: 2005.Georgia Field Report:Field Trip Earth, http://www.fieldtripearth.org/article.xml?id=1156

9. Katzner, T.E. 2005. Notes from the field..... Bird Calls 19(2):1. *(National Aviary newsletter)*

8. Katzner, T.E. 2004. Vultures on the verge. . . of a biological breakdown. Wildlife Conservation. 107:44-47. Reprinted in Bird Calls 19(2);6-7. *(National Aviary newsletter)*

7. Contributor: 2003. Kazakhstan Field Report:Field Trip Earth, http://www.fieldtripearth.org/article.xml?id=901

6. Katzner, T.E. 2003. Eagles and vultures in Kazakhstan. Luncheon presentation. The Nature Conservancy, International Development Office, New York, NY.

5. Katzner, T.E. 2003. An eagle's-eye view. Wildlife Conservation. 106:4-5.

4. Katzner, T.E. 1999. Rainforest Expert: JASON Project. Arizona Science Center, Phoenix, AZ, U.S.A.

3. Katzner, T.E., R. Capitan and B.A. Andres. 1996. Checklist of summer birds of Ft. Richardson. Ft. Richardson Army Base, Anchorage, AK, U.S.A.

2. Katzner, T.E., R. Capitan and B.A. Andres. 1996. Otter Lake/Otter Lake to Sixmile Lake Nature Trail Guides. Ft. Richardson Army Base, Anchorage, AK, U.S.A.

1. Katzner, T.E. 1996. Snowshoe Hare Biology. Snowshoe Hare Moon Walk. Forest Service Moon Walk Series, U.S. Forest Service, Laramie, WY, U.S.A.

Photographic contributions: 2011. "Bats, Vultures and Owls Face More Tricks than Treats" National Geographic Daily News, 29 October 2011.

Photographic contribution: 2011. "The flight of the eagle." Steppe Magazine

Photographic contributions: 2009. "Inadvertent Extinction." Connect (AZA Magazine).

Photographic contributions: 2008. Seneca Rocks Audubon Society Newsletter.

Photographic contributions: 2008. "Golden Eagle Redux." Marcia Bonta, PA State Game News, Nov.

Photographic contributions: 2007. "Golden Eagle Days, Part II." Marcia Bonta, PA State Game News, Dec.

Photographic contributions: 2005. "Vultures of Georgia and the Caucasus" L. Gavashelishvili. 2005.

Photographic contributions: 2005. "A birdwatching guide to Georgia" Gavashelishvili et al. 2005.

ACADEMIC APPOINTMENTS, BIOLOGISTS & STUDENTS SUPERVISED

Employer	Title	Year
West Virginia University Division of Forestry and Natural Resources	Research Assistant Professor	2010 – present
Duquesne University Department of Biology	Lecturer, Adjunct Asst. Professor	2008 - 2010
University of Pittsburgh Department of Biology	Adjunct Assistant Professor	2006 - 2010
U.S. National Science Foundation & Imperial College London	Postdoctoral Research Fellow	2003-2005
Arizona State University Department of Biology	Lecturer	2002
Arizona State University Department of Biology	Teaching Associate	1996-1998, 2001
Coe College, Iowa Department of Biology	Lecturer	1995
University of Wyoming Department of Zoology and Physiology	Graduate Research Associate	1993-1994
University of Wyoming Department of Zoology and Physiology	Teaching Associate	1992-1993
Oberlin College, Ohio Department of Biology	Teaching Assistant	1990
Oberlin College, Ohio Department of Biology	Tutor	1989, 1991

Courses	Capacity	Subjects covered	Institution
Climate chg & Ecol syst.	Lead Instructor	Multiple topics	West Virginia University, 2012
Ecosystems	Guest Lecturer	Population Genetics	West Virginia University, 2011
Conservation Biology	Lead Instructor	Conservation Biology Seminar	University of Pittsburgh, 2009
Non-invasive mark-recap	Lead Instructor	Non-invasive mark-recapture	Duquesne University, PA, 2008, 2009
Mammalogy	Lead Instructor	All topics	Arizona State University, Sierra Anches Field Stn., 2002
Mammalogy	Lead Instructor	All topics	Coe College, 1995
Conservation Biology	Guest Lecturer	International Conservation	Indiana Univ. Pennsylvania, 2009
Population Biology	Guest Lecturer	Conservation Demography	University of Pittsburgh, 2008
Biodiversity	Guest Lecturer	Non-invasive pop. estimation	Westminster College, PA, 2007
Ecology	Guest Lecturer	Field Ecology	University of Pittsburgh, 2006
Field Sampling	Guest Lecturer	Field Sampling Tech.	Kostanay Pedagogical Institute (KZ) 2006
Bio Ethics	Guest Lecturer	Corruption & Conservation	Duquesne University, 2006
Mammalogy	Guest Lecturer	Population Ecology, Sampling	Arizona State University, 1998 2001
Conservation Biology	Guest Lecturer	Population Biology, Wildlife Management	Arizona State University, 1997 1998, 2000, 2001
Mammalogy	Teaching Assoc.	Mammal labs	Arizona State University, 1996, 1998, 2001
Wildlife Conservation	Teaching Assoc.	Field Techniques	Arizona State University, 1997, 98
General Biology	Teaching Assoc.	General labs	University of Wyoming, 1992, 93
Organismal Biology	Teaching Assist.	Biology labs	Oberlin College, 1990

ACADEMIC APPOINTMENTS, BIOLOGISTS & STUDENTS SUPERVISED (cont.)

Postdoc/Biologists	**Research Topic**	**Institution**
Jonathan Hall	Human dimensions of conservation biology 2012 – present	West Virginia University Morgantown, WV
Tricia Miller	Golden & bald eagle ecology & conservation 2012 – present	West Virginia University Morgantown, WV
Adam Duerr	Golden eagle movement & conservation 2011 – present	West Virginia University Morgantown, WV

Grad. Students	**Degree & Research Topic**	**Institution**
Julie Mallon	M.S. (expected 2015) *Flight behavior of American vultures*	West Virginia University Morgantown, WV
Sirimgul Zarapova	Ph.D. (delayed) *Seasonal bird migration*	Institute of Zoology Almaty, Kazakhstan
Shannon Behmke	M.S. (expected 2014; PCMI degree) *New world vulture environmental toxicology*	West Virginia University Morgantown, WV
Christina Slover	M.S. (expected 2014) *Impact of fire on Fernow breeding birds*	West Virginia University Morgantown, WV
Andrew Dennhardt	M.S. (expected 2014) *Golden Eagle pop. size estimate & movement*	West Virginia University Morgantown, WV
Joshua Daniel	M.S. (expected 2014) *Black bear home range & habitat use*	West Virginia University Morgantown, WV
Yula Kapetanakos	Ph.D. (expected 2013) *Non-invasive demography of Asian vultures*	Cornell University Ithaca, NY
Maria Wheeler	Ph.D. (expected 2014) *Population genetics of US golden eagles*	Duquesne University Pittsburgh, PA
Almat Abayev	Ph.D. (delayed) *Migration of birds of prey*	Institute of Zoology Almaty, Kazakhstan
Trish Miller	Ph.D. (2012) *Golden eagle migration & wind power*	The Pennsylvania State University State College, PA

Grad. Committees	**Degree & Research Title**	**Institution**
Jacob Berl	M.S. (expected 2014) *Ecology of red headed woodpeckers*	West Virginia University Morgantown, WV
Glenna Schmid	M.S. (2012) *Aging birds via Pentosodine*	West Virginia University Morgantown, WV
Crissa Cooey	Ph.D. (expected 2014) *Pentosidine aging & cormorant management*	West Virginia University Morgantown, WV
Jesse Fallon	Ph.D. (expected 2013) *Physiological injury to birds from oil spills*	Virginia Tech Blacksburg, VA
Jennifer Gabel	Ph.D. (2007) *Gene flow & frag. anal. of Cherokee Darter*	Duquesne University Pittsburgh, PA

Undergrad Students	**Degree & Research Topic**	**Institution**
Mika Burdette	Undergraduate research (2012) *Window birdstrike on campus*	West Virginia University Morgantown, WV
Matthew Kneitel	Undergraduate research (2012) *Survey of heavy metals in birds*	West Virginia University Morgantown, WV
Cathy House	Undergraduate research (2011) *Peregrine falcon feeding behavior*	University of Pittsburgh Pittsburgh, PA
Andrew McCarty	Undergraduate research (2010) *Golden eagle population assessment*	University of Pittsburgh Pittsburgh, PA
Kevin McKinski	Undergraduate research (2010) *Peregrine falcon dispersal*	University of Pittsburgh Pittsburgh, PA

ACADEMIC APPOINTMENTS, BIOLOGISTS & STUDENTS SUPERVISED (cont.)

Undergrad Students	Degree & Research Topic	Institution
Lukas Musher	Undergraduate research (2010) *Evaluating declines of Caprimulgiformes*	University of Pittsburgh Pittsburgh, PA
Laura Loeser	Undergraduate research (2010) *Causes and distribution of raptor rehab*	California Univ. of Penn. California, PA
Emily Pearson	Undergraduate research (2009) *Designing a Dominican Republic Bird Trail*	University of Pittsburgh Pittsburgh, PA
Lukas Musher	Undergraduate research (2008 – 2009) *Avian communities of Pittsburgh's parks*	University of Pittsburgh Pittsburgh, PA
Cathy House	Undergraduate research (2009-2010) *Peregrine falcon feeding behavior*	University of Pittsburgh Pittsburgh, PA
Julia Winton	Undergraduate research (2008 – 2009) *Dispersal of Peregrine Falcons in PA*	National Aviary Pittsburgh, PA
Alexander Sagalov	Diplome (2001) *Variability in diet of imperial eagles*	University of Kustanay Kustanay, Kazakstan
Alexander Popkov	Diplome (2001) *Habitat associations of eagle prey*	University of Kustanay Kustanay, Kazakstan
Seth Layman	B.A. Biology (1999) *Parasites of eagle chicks*	The Colorado College Colorado Springs, CO
Anatoly Taran	Diplome (1999) *Eagle predator-prey interactions*	University of Kustanay Kustanay, Kazakstan

Other Students	Degree & Research Topic	Institution
Jacob Cohen	High-school research (2009, 2010) *Diet of urban peregrine falcons* Regional winner, Science Olympiad, SW PA	National Aviary Pittsburgh, PA

RESEARCH AND CONSULTATION APPOINTMENTS

Employer	Title	Year
West Virginia University Division of Forestry & Natural Resources	Research Assistant Professor	2010 – present
National Aviary Conservation & Field Research	Director	2005 - 2010
Hawk Mountain Sanctuary Association Acopian Center	Research Associate	2003 - present
Wildlife Conservation Society International Programs	Research Associate	2000 - present
Desert Botanical Garden, Arizona Research Office	Biological Consultant	1997
U.S. Fish and Wildlife Service, Alaska Migratory Bird Management	Biological Technician	1996
University of Wyoming Department of Zoology and Physiology	Research Associate	1995-1996
National Biological Service, Idaho Raptor Res. and Tech. Assist. Center	Research Associate, Field Crew Leader	1995
University of Wyoming Department of Zoology and Physiology	Biological Technician	1994
U.S. Fish and Wildlife Service, Hawaii Hawaii Field Station	Biological Technician	1992
Associate Colleges of the Midwest, Minnesota Wilderness Field Station	Research Associate	1992
Oberlin College, Ohio Department of Biology	Research Technician	1990-1991

ADVISORY BOARD MEMBERSHIP

Advisory Committee: Sociedad Ornitología de la Hispaniola (SOH; 2005 - 2010)
Scientific Advisor: Philippine Eagle Foundation (2006 - 2010)
Scientific Advisor: American Zoo and Aquarium Associations (AZA) Raptor Taxon Advisory Group (TAG). (2004 - present)
Scientific Advisor: American Zoo and Aquarium Associations (AZA) Cinereous Vulture Species Survival Plan (SSP). (2004 - present).

SERVICE RELATED ACTIVITIES

Elected Councilor, Wilson Ornithological Society. 2012 – 2015.
Member, Invited Expert, AWWI Eagle Expert Workshop, Boulder, CO, 2012.
Member, Independent Science Panel, Desert Region Ecological Conservation Plan. Riverside, CA, 2012.
Member, Small Grant Awards Committee, Biological Field Station of Kostanay Pedagogical Institute, 2012 - present.
Chair, member, Division of Forestry and Natural Resources Seminar Committee, 2011 - present
Invited expert, Eagle Workshop: American Wind Wildlife Institute, November 2011.
Invited expert, Workshop on vultures in Israel, Society for the Protection of Nature, Israel, 2011.
Member, WVU Animal Care and Use Education and Training Focus Group, 2011 - present
Awards Committee, TWS Student Poster Presentations, West Virginia University Chapter. 2011.
Member, Conservation Committee, Raptor Research Foundation, 2011 - present
Member, Environmental Committee, United Jewish Federation of Pittsburgh. 2006 – present.
Member, Allegheny County "Green Action Team," Commissioned by Allegheny County Executive, 2008 – present
Member, American Zoo and Aquarium Association. Research Technical Committee, 2009-2011.
Member, Ornithological Technical Committee, State of Pennsylvania. 2006 - present.
Founder, coordinator, Eastern Golden Eagle Working Group, 2010 - present.
Chair, Environmental Committee, United Jewish Federation of Pittsburgh. 2009 – 2011.
Co-Chair, Climate Change Committee of the Allegheny County "Green Action Team," Commissioned by Allegheny County Executive, 2008 – 2010.
Chair, Local Organizing Committee, Wilson Ornithological Society & Association of Field Ornithologists, 2009 Joint Annual Conference, Pittsburgh, PA. 2006-2009.
Member, Scientific Program Committee, Wilson Ornithological Society & Association of Field Ornithologists, 2009 Joint Annual Conference, Pittsburgh, PA. 2006-2009.
Member, Search Committee, Rea Postdoctoral Fellow, Carnegie Museum of Natural History, 2009.
Member, Institutional Animal Care and Use Committee (IACUC), VA Pittsburgh Healthcare System, 2008 – 2010.
Member, Institutional Biosafety Committee (IBC), VA Pittsburgh Healthcare System, 2008 – 2010.
Co-chair and **Member**. Young Professionals Initiatve, World Affairs Council of Pittsburgh. 2008–2009.
Advisor, Conservation and Science Committee, Board of Directors, Phipps Botanical Garden. 2007-2010.
Member, Pittsburgh Zoo Conservation Grant Committee, Pittsburgh Zoo, 2007.
Member, Search Committee, Conservation Biologist Search, Powdermill Nature Reserve, Carnegie Museum of Natural History. 2006-2007
Co-chair, member, Institutional Animal Care and Use Committee (IACUC), National Aviary/Pittsburgh Zoo and PPG Aquarium, 2005 – 2010.
Graduate Student Representative, faculty search committee, Department of Biology, ASU. 2002.
Graduate Student Representative, faculty search committee, Department of Biology, ASU. 2000-2001.
Graduate Student Representative (Ecology), Department of Biology, ASU. 2000-2001.
Member, organizing committee for "Graduate training in the biological sciences" seminar series, Department of Biology, ASU. 2000-2001.

PROFESSIONAL ORGANIZATIONS AND ACTIVITIES

Wildlife Conservation Society of the Philippines. 2005 – present.
Georgian Center for the Conservation of Wildlife (GCCW) 2004 - present.
American Ornithologists Union. 1993-present.
American Society of Mammalogists. 1993 - present.
Cooper Ornithological Society. 1998-present.
Raptor Research Foundation. 1998-present.
Society for Conservation Biology. 1996- present.
Wilson Ornithological Society. 1998-present.
Ecological Society of America. 1997-2003.
Central Arizona Chapter, Society for Conservation Biology. Member 1997-2002. President, 1997.
Asian Raptor Research and Conservation. 1999-2001.
World Working Group on Birds of Prey and Owls. 1999-2001.

EDITORIAL AND REVIEWING ACTIVITY

Editor: Animal Conservation (2007 - present)
Review Panel: U.S. National Science Foundation (2010)
Book reviews: Yale University Press (2008)
Review Board (grants): National Birds of Prey Trust (2005-present)
Review Panel: Association of Zoos and Aquariums Conservation Endowment Grant Program (AZA-CEF; 2008)
Editorial Board: Animal Conservation (2005 - 2006)
Editor and compiler: Reports of the Workshop "Conservation of *Gyps* vultures in Asia." North American Ornithological Conference (2002)
Editor and compiler: Reports of the Workshop "Indian griffon vultures and their problems." 4th Eurasian Congress on Raptors (2001)
Reviewing (2012): National Geographic Society, Virginia Department of Game and Inland Fisheries Bald Eagle Management Guidelines, Small Grants Committee of Biological Field Station of KPGI, Kazakhstan (*7), Bird Study/Ringing & Migration (*2), Mike Madders Field Research Award (*2), Oryx, Journal of Raptor Research (*2), The Wildlife Society Bulletin, American Association of Zoos and Aquaria, Conservation Endowment Fund (AZA-CEF; *3), Canadian Journal of Zoology (*2), National Birds of Prey Trust (*22), Save Our Species (SOS) Grants of IUCN, Animal Conservation, Pittsburgh Zoo and PPG Aquarium - PPG Sustainability Fund (*7)
Reviewing (2011): International Foundation for Science (IFS), Save Our Species, IUCN Conservation Grants (*4), The Auk, Conservation Biology, Methods in Ecology and Evolution, American Institute of Biological Sciences: USFWS Population Status of Golden Eagles in North America, Mike Madders Field Research Award (*2), Conservation Leadership Program (*7), Ornitología Neotropical, USGS External Peer Review, Forktail; American Zoological and Aquarium Association Conservation Endowment Grant Program (AZA-CEF; *4), The Wildlife Society: USFWS Draft Land-based Wind Turbine Guidelines, Ibis (*2), Journal of Raptor Research, National Birds of Prey Trust (*17)
Reviewing (2010): American Institute of Biological Sciences: USFWS Bald and Golden Eagle Protection Act Standards for Review of Wind Energy Projects, Proceedings of the Royal Society, B: Biology, Forktail (*2), European Journal of Wildlife Research, Ibis (*2), U.S. National Science Foundation, The Auk, Animal Conservation, Basic and Applied Ecology (*2), Forest Ecology and Management, Acta Zoologica Bulgaria (*2), National Birds of Prey Trust (*4), Oryx (*2), Journal of Raptor Research (*2). American Zoological and Aquarium Association Conservation Endowment Grant Program (AZA-CEF; 6),
Reviewing (2009): U.S. National Science Foundation (2), The Auk, International Foundation for Science, American Zoological and Aquarium Association Conservation Endowment Grant Program (AZA-CEF; 6), Biological Conservation, Journal of Raptor Research, Acta Zoologica Bulgaria (*2), National Birds of Prey Trust.
Reviewing (2008): The Auk, Journal of Wildlife Management, Ibis, The Condor, Oryx (2), Ornis Fennica, Biological Conservation, Journal of Raptor Research (3), Journal of Mammalogy, Ardea, Mongolian Journal of Biology, Oecologia, Pittsburgh Zoo Conservation Fund Grant Program, American Zoological and Aquarium Association Conservation Endowment Grant Program (AZA-CEF; 5), Wildlife Conservation Society Research Fellowship Program (2), International Foundation for Science (Research Grants)

TIMOTHY H. KEITT
SECTION OF INTEGRATIVE BIOLOGY
UNIVERSITY OF TEXAS AT AUSTIN
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EDUCATION

1991-1995	*University of New Mexico:* Ph.D., Ecology and Evolutionary Biology
1988-1990	*University of Florida:* M.S., Environmental Engineering Sciences
1985-1987	*University of Florida:* B.A., Zoology

ACADEMIC POSITIONS

2009-	Associate Professor, University of Texas at Austin
2002-2009	Assistant Professor, University of Texas at Austin
2000-2002	Assistant Professor, State University of New York at Stony Brook

MEMBERSHIP IN GRADUATE PROGRAMS

2002-	Ecology, Evolution and Behavior, College of Natural Sciences, UT Austin
2008-	Division of Statistics and Scientific Computation, College of Natural Sciences, UT Austin

HONORS, AWARDS, FELLOWSHIPS

2010	Dean's Fellow, College of Natural Sciences, UT Austin
2010	Faculty Research Assignment, UT Austin
2010-2011	Foreign Scholar in Residence, *Estación Biológica de Doñana*, *Sevilla*, Spain
2009-2010	William H. and Gladys G. Reeder Fellowship in Ecology, UT Austin
2006	William H. and Gladys G. Reeder Fellowship in Ecology, UT Austin
2003	University of Texas Summer Research Assignment, Austin
1998	Fulbright Senior Scholar, *Potificia Universidad Católica de Chile*
1998-2000	Postdoctoral Fellow, National Center for Ecological Analysis and Synthesis
1995-1997	Postdoctoral Fellow, The Santa Fe Institute
1995	Honor Society of Phi Kappa Phi, University of New Mexico

LITERATURE CITATIONS

As of November 2012, Google Scholar reports a total of 3636 citations since 1996 or roughly 230 per year. Twenty-six of these papers have received 26 or more citations (H = 26). Expected number of citations per paper is approximately 68. Highly cited papers are indicated below.

PUBLICATIONS

In Review

Belaire, J., B.J. Kreakie, **T. H. Keitt**, and E. Minor. Whooping crane stopover habitat in the central US: recommendations for wind energy development. *Ecological Applications*.

Behrman, K.D. and **T. H. Keitt**. Hierarchical decomposition of the species-energy relationship by scale. *Global Ecology and Biogeography*.

2012

Keitt, T. H. 2012. Productivity, nutrient imbalance and fragility in coupled producer–decomposer systems. Ecological Modelling, 245, 12–18.

Lasky, J. R., Des Marais, D. L., McKay, J. K., Richards, J. H., Juenger, T. E., and **T. H. Keitt**. 2012. Characterizing genomic variation of Arabidopsis thaliana: the roles of geography and climate. Molecular Ecology.

Lasky, J. R., and **T.H. Keitt**. 2012. The Effect of Spatial Structure of Pasture Tree Cover on Avian Frugivores in Eastern Amazonia. Biotropica, 44(4), 489–497.

Kreakie, B. J. and **T. K. Keitt**. 2012. Integration of distance, direction and habitat into a predictive migratory movement model for blue-winged teal (*Anas discors*). *Ecological Modelling*, 224:25-32.

Pinto, N., **Keitt, T. H.**, and Wainright, M. 2012. LORACS: JAVA software for modeling landscape connectivity and matrix permeability. Ecography, 35(5), 388–392.

Kreakie, B.J., Fan, Y., and **T. H. Keitt**. Enhanced Migratory Waterfowl Distribution Modeling by Inclusion of Depth to Water Table Data. *PlosOne*.

Behrman, K.D., Kiniry, J.R., Juenger, T.E., Winchell, M., and **T. H. Keitt**. Spatial forecasting of switchgrass under current and future climate change scenarios. *Ecological Applications*.

Kiniry, J. R., Anderson, L. C., Johnson, M.-V. V., Behrman, K. D., Brakie, M., Burner, D., Cordsiemon, R. L., et al. (2012). Perennial Biomass Grasses and the Mason–Dixon Line: Comparative Productivity across Latitudes in the Southern Great Plains. BioEnergy Research.

2011

Lasky J. R., W. Jetz and **T. H. Keitt**. 2011. Conservation biogeography of the US-Mexico border: a transcontinental risk assessment of barriers to animal dispersal. *Diversity and Distributions* 17:673-687. **(Highlighted in *Nature News*.)**

Avnery, S., R. A. Dull and **T. H. Keitt**. (2011). Human versus climatic influences on late-Holocene fire regimes in southwestern Nicaragua. *The Holocene* Sept: 1-8.

Noble, A. E., N. M. Temme, W. F. Fagan and **T. H. Keitt**. 2011. A sampling theory for asymmetric communities. *Journal of Theoretical Biology* 273:1-14.

2010

Economo, E. and **T. H. Keitt**. 2010. Network isolation and local diversity in neutral metacommunities. *OIKOS* 119:1355-1363.

Lasky J. R. and **T. H. Keitt**. 2010. Spatial variation in the abundances of dry forest bird species and functional groups along environmental gradients. *Journal of Tropical Ecology* 26:67-78.

2009

Keitt, T. H. 2009. Habitat conversion, extinction thresholds and pollination services in agroecosystems. *Ecological Applications* 19:1561-1573.

Brooks, C. P., C. Holmes, K. Kramer, B. Barnett and **T. H. Keitt**. (2009). The role of demography and markets in determining deforestation rates near Ranomafana National Park, Madagascar. PloS one, 4(6), e5783

Pinto N. and **T. H. Keitt**. 2009. Beyond the least cost path: evaluating corridor robustness using a graph-theoretic approach. *Landscape Ecology* 24:253-266. **(Faculty of 1000 "must read")**

2008

Keitt, T. H. 2008. Coherent ecological dynamics induced by large scale disturbance. *Nature* 454:331-334. **(Faculty of 1000 recommended reading.)**

Economo, E. and **T. H. Keitt**. 2008. Species diversity in neutral metacommunities: a network approach. *Ecology Letters* 11:52-62. **(Faculty of 1000 recommended reading)**

McRae, B. H., B. G. Dickson, **T. H. Keitt** and V. B. Shah. 2008. Using circuit theory to model connectivity in ecology, evolution and conservation. *Ecology* 89:2712-2724 **(GS 135 citations)**

Brooks, C. P., J. Antonovics and **T. H. Keitt**. 2008. Spatial and temporal heterogeneity explain disease dynamics in a spatially-explicit network model. *The American Naturalist* 172:149-159

Downing, A. L., B. L. Brown, E. M. Perrin, **T. H. Keitt**, M. A. Leibold. 2008. Environmental fluctuations induce scale-dependent compensation and increase stability in plankton ecosystems. *Ecology* 89:3204-3214.

Pinto N. and **T. H. Keitt**. 2008. Scale-specific responses to forest cover displayed by frugivore bats. *OIKOS* 117:1725-1731.

Pinto N., J. Lasky, R. Bueno, **T. H. Keitt** and M. Galetti. 2008. "Primate Densities in the Brazilian Atlantic Forest: The Role of Habitat Quality and Anthropogenic Disturbance," in *South American Primates: Comparative Perspectives in the Study of Behavior, Ecology, and Conservation,* P. A. Garber, A. Estrada, J. C. Bicca-Marques, E. W. Heymann, K. B. Strier, eds. Springer.

2007

Keitt, T. H. 2007. ``On the quantification of local variation in biodiversity scaling using wavelets," in *Scaling Biodiversity*, D. Storch, P. A. Marquet and J. H. Brown, eds. Cambridge University Press, Cambridge.

Kremen, C., N. M. Williams, M. A. Aizen, B. Gemmill-Herren, G. LeBuhn, R. Minckley, L. Packer, S. G. Potts, T. Roulston, I. Steffan-Dewenter, D .P. Vazquez, R. Winfree, L. Adams, E. E. Crone, S. S. Greenleaf, **T. H. Keitt**, A. M. Klein, J. Regetz and T. H. Ricketts. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters* 10:299-314**. (GS 264 citations)**

2006

Keitt, T. H. and J. Fischer. 2006. Detection of scale-specific community dynamics using wavelets. *Ecology* 87:2895-2904.

2005

Keitt, T. H. and D. L. Urban. 2005. Scale-Specific Inference Using Wavelets. *Ecology* 86: 2497-2504. **(Faculty of 1000 recommended reading)**

Holt, R. D. and **T. H. Keitt**. 2005. Species' borders: a unifying theme in ecology. *OIKOS* 108:3-6. **(Faculty of 1000 "must read"; GS 107 citations)**

Fortin, M.-J., **T. H. Keitt**, B. A. Mauer, M. L. Taper, D. M. Kauffman and T. M. Blackburn. 2005. Species' geographic ranges and distributional limits: pattern analysis and statistical issues. *OIKOS* 108: 7-17.

Holt, R. D., **T. H. Keitt**, M. A. Lewis, B. A. Mauer and M. L. Taper. 2005. Theoretical models of speices' borders: single species approaches. *OIKOS* 108:18-27. **(GS 129 citations)**

Case, T. J., R. D. Holt, M. A. McPeek and **T. H. Keitt**. 2005. The community context of species' borders: ecological and evolutionary perspectives. *OIKOS* 108:28-46. **(GS 149 citations)**

Johnson, S. E., P. C. Wright, **T. H. Keitt**, K. L. Kramer, F. J. Ratelolahy, G. Ravalison, C. M. Holmes, W. Gordon, J. P. Puyravaud. 2005. Predictors of local variation in lemur abundance at Ranomafana National Park, Madagascar. *American Journal of Physical Anthropology*. Suppl. abstracts.

2003

Keitt, T. H. 2003. ``Network theory: an evolving approach to landscape conservation," in *Ecological Modeling for Resource Management*, V. H. Dale, editor. Springer-Verlag, Berlin.

Keitt, T. H. 2003. ``Spatial autocorrelation and the maintenance of source-sink populations," in *How Landscapes Change: Human Disturbance and Ecosystem Fragmentation in the Americas*, G. A. Bradshaw and P. A. Marquet, eds. Springer-Verlag, Berlin.

2002

Keitt, T. H., O. N. Bjornstad, P. Dixon and S. Citron-Pousty. 2002. Accounting for spatial pattern when modeling environment-abundance relationships. *Ecography* 25:616-625. **(GS 228)**

Keitt, T. H., L. A. N. Amaral, S. V. Buldyrev and H. E. Stanley. 2002. Scaling in the growth of geographically subdivided populations: invariant patterns from a continent-wide biological survey. *Philosophical Transactions of the Royal Society of London, Series B* 357:627-633.

2001

Keitt, T. H., M. A. Lewis and R. D. Holt. 2001. Allee dynamics, invasion pinning, and species' borders. *The American Naturalist* 157:203-216. **(GS 227 citations)**

Urban D. L. and **T. H. Keitt**. 2001. Landscape connectedness: a graph theoretic perspective. *Ecology* 82:1205-1218. **(GS 437 citations)**

2000

Keitt, T. H. 2000. Spectral representation of neutral landscapes. *Landscape Ecology* 15:479-494. **(GS 100 citations)**

Bunn, A. G., D. L. Urban and **T. H. Keitt**. 2000. Landscape connectivity: a conservation application of graph theory. *Journal of Environmental Management* 59:265-278. **(GS 247 citations)**

Stanley H. E., L. A. N. Amaral, P. Gopikrishnan, P. Ch. Ivanov, **T. H. Keitt** and V. Plerou. 2000. Scale invariance and universality: organizing principles in complex systems. *Physica A* 281:60-68.

Kendall, B. E., O. N. Bjornstad, J. Bascompte, **T. H. Keitt** and W. F. Fagan. 2000. Dispersal, environmental correlation, and spatial synchrony in population dynamics. *The American Naturalist* 155:628-636. **(GS 155 citations)**

Holt, R. D. and **T. H. Keitt**. 2000. Alternative causes for range limits: a metapopulation perspective. *Ecology Letters* 3:41-47. **(GS 130 citations)**

1999

Micheli, F., K. L. Cottingham, J. Bascompte, O. N. Bjornstad, G. L. Eckert, J. M. Fischer, **T. H. Keitt**, B. E. Kendall, J. L. Klug and J. A. Rusak. 1999. The dual nature of community variability. *OIKOS* 85:161-169.

1998

Keitt, T. H. and H. E. Stanley. 1998. Dynamics of North American breeding bird populations. *Nature* 393:257-260. **(GS 121 citations)**

Stanley, H. E., L. A. N. Amaral, S. V. Buldyrev, S. Havlin, **T. H. Keitt**, H. A. Makse and G. Viswanathan, ``Scale-Invariant Correlations in the Social Sciences," in *Econophysics: An Emerging Science* [Proc. 1997 Budapest Conference], J. Kertesz and I. Kondor, eds. (Kluwer, Dordrecht, 1998).

1997

Keitt, T. H., D. L. Urban and B. T. Milne. 1997. Detecting critical scales in fragmented landscapes. *Conservation Ecology* [http://www.consecol.org/] 1:4. **(GS 334 citations)**

Keitt, T. H. 1997. Stability and complexity on a lattice: coexistence of species in an individual-based food web model. *Ecological Modelling* 102:243-258.

1996

Keitt, T. H. and P. Marquet. 1996. The introduced Hawaiian avifauna reconsidered: evidence for self-organized criticality? *Journal of Theoretical Biology* 182:161-167.

Milne, B. T., A. R. Johnson, **T. H. Keitt**, C. A. Hatfield, J. David and P. Hraber. 1996. Detection of critical densities associated with pinon-juniper woodland ecotones. *Ecology* 77:805-821.

Keitt, T. H., A. Franklin and D. L. Urban. 1996. Landscape analysis and metapopulation structure. Chapter II.3 in USDI Fish and Wildlife Service, Recovery Plan for the Mexican Spotted Owl: Vol.I., Albuquerque, NM. 172pp.

1995

Keitt, T. H. and A. R. Johnson. 1995. Spatial heterogeneity and anomalous kinetics: emergent patterns in diffusion-limited predator-prey interactions. *Journal of Theoretical Biology* 172:127-139.

EXTRAMURSAL SUPPORT

Current

NSF "Collaborative Research: Incorporating physiological variation in mechanistic range models for ecological forecasting." 2011-2014 (PI; $148,091)

NSF "GERP: The Physiological Genomics of *Panicum*: Exploring switchgrass responses to climate change." 2009-2012 (co-PI with Juenger, Hawkes, Fay; $4.7 million)

Past

DOE National Institute for Climate Change Research, "Improved prediction of climate change impact on migratory pathways through machine learning, hydrological modeling and network theory." 2009-2011 (PI; $250,000)

NOAA "Genetic connectivity and evolution of resiliency to stress in Micronesian corals." 2009-2011 (co-PI with Matz, Palumbi; $70,000)

Marine Ecosystem-Based Tools Innovation Fund (David and Lucile Packard Foundation; Duke University) "NAMEM: Network Analyst for Marine Ecosystem-based Management," 2007-2009 (PI; $110,000)

Texas Space Grant Consortium (NASA) New Investigator Award: "Mapping Pattern and Process Across Complex Landscapes Using Remote Sensing and GIS," 2006-2009 (PI; $20,000).

David and Lucile Packard Foundation, "Integrating Dynamics of Human Resource Use and Their Effects on Rainforests in Madagascar", 2002-2007 (co-PI with Wright; $1,000,220).

Fulbright Foundation of Chile, "Geostatistical analysis of species-climate relationships across the Americas," 1998 (PI; $10,000).

USDA Fish and Wildlife Service, Research involved modeling and GIS analysis of

Mexican Spotted Owl habitat use at local and regional scales, 1994-1995 (PI; $35,000).

SPEAKING INVITATIONS

2011	Department seminar, "Wavelet analysis of complex ecological patterns in space and time", Texas Tech University
2010	Departmental seminar, "Disentangling ecological complexity", AMAP, Montpellier, France
	Departmental seminar, "Wavelet analysis of time series", Heart Institute, Corpus Christi
2009	Invited Foreign Lecturer, II Jornadas Argentinas de Ecología de Paisajes, Córdoba City, Argentina
2008	Departmental seminar, "Disentangling hierarchical patterns in space and time: wavelets and landscape networks," Rice University
	Departmental seminar, "Wavelet analysis of biological diversity," Biological Sciences, UC San Diego
	Symposium presentation, "Scale-specific drivers of community turnover in a continent-wide biological survey," US IALE, Madison
	Symposium presentation, "Species diversity in structured metacommunities: A network approach," US IALE, Madison
2007	Graduate lectures, "Concepts and methods of spatial graph theory" and "Network theory for spatial risk mapping," *Networks in Ecology and Beyond* organized by the Program in Interdisciplinary Math, Ecology and Statistics at Colorado State University, Fort Collins
	Symposium presentation, "Habitat Conversion, Extinction Thresholds and Pollinator Services in Agroecosystems," US IALE, Tucson
	Departmental seminar, "Modeling persistence of pollinators in agroecosystems," Department of Ecology and Evolutionary Biology, UC Santa Cruz
2006	Departmental seminar, "Wavelets as a Paradigm for Pattern and Scale in Ecology," Department of Biology, University of Puerto Rico
	Symposium presentation, "Applications of network theory to landscape conservation," U.S. IALE, San Diego
	Symposium presentation (co-organizer), "Theory and application of ecological networks," Ecological Society of America, Memphis
	Graduate lecture, "Robustness, resistance and resiliency in landscape networks", *Social and Ecological Networks: Theories and Applications* Ph.D. course organized by T. Elmqvist, Stockholm
2005	Workshop presentation (co-organizer), "Spatial network theory: applications and conceptual domain," Santa Fe Institute, Santa Fe

2004	Workshop presentation, "On the quantification of local biodiversity scaling using wavelets," *Scaling Biodiversity* organized by Santa Fe Institute, Prague
	Departmental seminar, "Spectral representation of pattern and scale in ecology," Institute for Ecosystem Studies, Millbrook
2002	Symposium presentation, "Network theory for landscapes: application to Chilean temperate rainforest fragments," Annual Meeting of the Biological Society of Chile, Termas de Puyehue
	Symposium presentation, "Allee effects and invasion pinning," Ecological Society of America, Tucson
2001	Symposium presentation, "Analysis of landscape flow networks," Annual Meeting of the Biological Society of Chile, Termas de Puyehue
1999	Symposium presentation, "Graph theoretical approaches to landscape connectivity," 5th IALE World Congress, Snowmass
	Symposium presentation, "Allee effects and species borders," 5th IALE World Congress, Snowmass
1998	Departmental seminar, "Application of landscape networks," Department of Biological Sciences, P. Univ. Católica de Chile, Santiago
1997	Symposium presentation, "Landscape modeling: the addition of spatial complexity," 4th Annual Meeting of the Wildlife Society, Snowmass
	Graduate lecture, "Scaling in ecology," Santa Fe Institute Summer School

APPLIED CONSERVATION EXPERIENCE

1995	Auxiliary member of the USFWS recover team for the Mexican Spotted Owl (*Strix occidentalis lucida*)
2000-2004	Research, training and outreach in support of Lemur conservation in Madagascar

PROGRAMMING AND SOFTWARE

Expert C/C++ programmer

Expert R programmer, including C/C++ internals

Past experience with Fortran, Pascal, Perl, Matlab/Octave, Sather

Expert in PostgreSQL database programming, including server-side C/C++ internals

Expert in the Boost Graph Library (C++)

Wrote among the first R packages linking R to a relational database system (PostgreSQL)

Lead author of "rgdal", an R package linking R to the Geospatial Data Abstraction Library. Provide GIS capability in R and is used by 1000's of researchers worldwide.

Expert UNIX/Linux system and network administrator, including high performance cluster computing

Experience programming Bayesian models using the WinBUGS/JAGS/STAN syntax

WORKING GROUPS

2007-2009	Member, "Mechanistic distributions models: energetics, fitness, and population dynamics," joint NCEAS/NESCent working group
2005-2007	Member, "Restoring an ecosystem service to degraded landscapes: native bees and crop pollination" working group, NCEAS, Santa Barbara
1999-2000	Member, "Integrating the statistical modeling of data in ecology" working group, NCEAS, Santa Barbara
1998-2000	Member, "The ecology and evolutionary dynamics of species' borders" working group, NCEAS, Santa Barbara

SERVICE

Workshop & Symposium Organizer

Symposium: Ecological and evolutionary dynamics in complex networks (with Bill Fagan), 91st Meeting of the Ecological Society of America, Memphis (August 2006)

Workshop: Network Robustness to Evolving Agents (with Lauren Meyers), Santa Fe Institute (January 2005)

Workshop: Integrating Dynamics of Human Resource Use and Their Effects on Rainforests in Madagascar (with Patricia Wright), Ranomafana, Madagascar (December 2002)

University Service

Graduate workshop on niche modeling methods, March 24, 2007

Graduate selection committee, UT Ecology, Evolution and Behavior, 2006-2009

Environmental sciences faculty search committee, UT Environmental Sciences Institute and Section of Integrative Biology, 2003

Ecosystem ecologist faculty search committee, SUNY Stony Brook, 2001

Conservation biology faculty search committee, SUNY Stony Brook, 2002

Referee & Grant Reviewer

National Science Foundation, Nature, Ecology, Ecological Monographs, OIKOS, Ecography, Journal of Biogeography, Ecosystems, Landscape Ecology, Complexity, Conservation Biology, Environmental Science & Technology, Journal of Theoretical Biology, Natural Sciences and Engineering Research Council of Canada, Philosophical

Transactions of the Royal Society of London B, Journal of Animal Ecology, Mathematical Biosciences, The American Naturalist, Ecological Modeling

Service To Professional Organizations

Secretary-treasurer, Theory Section of the Ecological Society of America, 1998-2000
Editorial board, Landscape Ecology, 2009-2012

Educational Outreach Activities

Instructor, "Kids do Ecology" program at the National Center for Ecological Analysis and Synthesis, UC Santa Barbara

Software Development

"Network Analyst for Marine Ecosystem-based Management" and "PostGraph" library; network analysis software.
Contributed 5 packages to R (http://www.r-project.org/)
rpgsql - one of first relational database access packages for R
Rdbi - generic framework for database access
Rdbi.PgSQL - Rdbi driver package for PostgreSQL
rgdal - geomatics in R
trifield – ternary heatmaps and contours

TEACHING AND ADVISING

Graduated Ph.D. Students

Naiara Sardinha-Pinto (2008)
Evan Economo (2009)
Betsy Reardon (2011)
Katherine Behrman (2011)
Jesse Lasky (2012)

Ph.D. Students Moved To Candidacy

Tania Pena-Blanca (2008)

Ph.D. Students

Colin Addis (2010)
Andria Salas (2011)

Graduated M.S. Students

Courtney Abshire (2010)

Undergraduate Honors Students

Kevin Hannay, Mathematics and Physics (2006-2008)
Jeff Scott, Biology (2008)

Postdoctoral Associates

Wendy Gordon (2002-2003; Ecological Consultants)
Chris Brooks (2006-2007; faculty Mississippi State University)
Andrew Noble (2008-2009; research faculty, Univ. of Maryland)

Courses Taught

University of Texas
BIO 373 Ecology
BIO 384K Mathematical Ecology
BIO 384K Topics in Biogeography
BIO 384D Advanced Topics in Ecology, Evolution and Behavior
SUNY Stony Brook
Non-majors Ecology
Graduate Core Ecology

Carl James Schwarz
Professor / Statistics and Actuarial Science
Simon Fraser University

Educational Background

2010	PStat	Statistics, American Statistical Association, United States The P.Stat. designation represents accreditation as a Professional Statistician by the American Statistical Association. Details about accreditation available at *http://www.amstat.org/accreditation/index.cfm*
2004	P.Stat.007	Statistics, Statistical Society of Canada, Canada The P.Stat. designation represents accreditation as a Professional Statistician by the Statistical Society of Canada. Details about accreditation available at *http://www.ssc.ca/en/accreditation/brief-summary-accreditation*.
1988	Ph.D.	Statistics, University of Manitoba, Canada Post-release stratification and migration models in band-recovery and capture-recapture models
1981	M. Math	Statistics, University of Waterloo, Canada
1980	M.Sc.	Computer Science Simulation and modeling, University of Manitoba, Canada
1978	B.Sc.	Computer Science, University of Manitoba, Canada

Employment History at Academic Institutions

September 2001 - Current	Professor, Statistics and Actuarial Science, Simon Fraser University
September 2001 - August 2004	Chair, Department of Statistics and Actuarial Science, Simon Fraser University
January 1994 - August 2001	Associate Professor, Department of Statistics and Mathematics, Simon Fraser University
July 1988 - December 1993	Assistant Professor, Department of Statistics, University of Manitoba
September 1987 - July 1988	Lecturer, Department of Statistics, University of Manitoba
September 1984 - July 1988	Consultant, Statistical Advisory Service, University of Manitoba
September 1984 - August 1987	Sessional Lecturer, Department of Statistics, University of Manitoba

Current Research Interests

Statistics - experimental design; ANOVA; STATISTICAL CONSULTING

My research program is in three areas: capture-recapture modeling of animal population dynamics; statistical consulting; and linear and generalized linear models. The research in capture-recapture models requires the development of new stochastic models, the development of model fitting and testing procedures, and the development of computer software. In large part, it is motivated by real problems encountered by ecologists. My interest in statistical consulting involves assistance in experimental design and analysis in complex experimental situations where the "standard textbook" results are not appropriate. Both of these areas give rise to my interest in linear and generalized linear models.

My current research projects are:

- the development of capture-recapture methodology to estimate population parameters of temporally stratified populations. This has applications in estimating salmon escapement; in estimating salmon smolt runs; and in estimating sable fish populations.

- the development of capture-recapture methodology to estimate population parameters of long-lived animal populations that have temporary absences from the sampling areas. This will be applied to estimate the population size and survival rates of the seal herd on Sable Island, Nova Scotia. This population consists of long-lived animals with year-to-year temporary absences from the breeding colony, and within-year temporary absences from the beaches during multiple within-year surveys.the development of tag-recovery methodology to study migration among geographically-stratified populations. This has been used to study the movement of herring among spawning areas in B.C. and the movement of mallards among wintering areas in the southern United States. A new study is underway to examine the movement of hatchery released salmon from the coded-wire returns obtained from the fishery.

- the provision of statistical advice (through the Statistical Advisory Service) to graduate students and faculty at the University and to researchers off campus. For example, we are currently involved in a project to investigate the relationship between forest inventory data stored in a GIS and habitat data obtained by ground crews.

Dissemination of the research findings is through publications in refereed journals. However, because of the time lag between completion of a research project and the eventual publication in a journal, I also regularly give presentations at conferences where the users of the research are most likely to attend and have given workshops to transfer the results to ecologists. My work in statistical consulting is important for similar reasons - to ensure that modern methods in statistics are effectively used in other disciplines.

Refereed Publications

Huston, C. and Schwarz, C. J. (2012). Hierarchical Bayesian strategy for modeling correlated compositional data with observed zero counts.. Environmental and Ecological Statistics (EEST) 19, 327-344. *DOI: 10.1007/s10651-012-0189-0*.

Bonner, S. B. and Schwarz, C. J. (2011). Smoothed estimates for time-stratified mark-recapture experiments using Bayesian p-splines. Biometrics 67, 1498-1507. *DOI: 10.1111/j.1541-0420.2011.01599.x*.

Mirhady, D. C. and Schwarz, C . J. (2011). Dikastic participation. Classical Quarterly, 61, 744.767. *DOI:10.1017/S0009838811000176*.

Forsman, E.D., Anthony, R.G., Dugger, K.D., Glenn, E.M., Franklin, A.B., White, G.C., Schwarz, C.J., Burnham,K.P., Anderson, D.R., Nichols, J.D., Hines, J.E., Lint, J.B., Davis, R.J., Ackers, S.H., Andrews,L.S., Biswell, B.L., Carlson, P.C., Diller, L.V., Gremel, S.A., Herter, D.R.,, Higley,J.M., Horn,R.B., Reid, J.A., Rockweit, J., Schaberel, J., Snetsinger, T.J., and Sovern. S.G. (2011). Population demography of Northern Spotted Owls. Studies in Avian Biology, 40, 1-106.

Sutherland, J. M., Castelluccio, P., and Schwarz, C. J. (2009). A multi-level model for continuous time population estimation. Biometrics 65, 841-849. *DOI: 10.1111/j.1541-0420.2008.01129.x*

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APPENDIX D

Webinar Presentation and Associated Minutes
for the
Peer Review of the Eagle Fatality Model
and its
Application to Wind Energy Development Projects
for the
U.S. Fish and Wildlife Service

Webinar Agenda for 3rd Party Review of USFWS Eagle Model

When: **Friday January 18, 2013**

Time: **12:30 MST**

Conference Call Info: **Call in Phone No. = 877-920-8202/ Passcode = 68700503**

- **Welcome/Introduction (*Casey*) - 5 min.**

- **Background (*Brian*)- 15 min.**
  - *BRIEF* history of the basic Service model (evolution, ECPG, etc.)
  - "Predicting (& Permitting) Eagle Fatalities in the Face of Uncertainty"
    - Constraints on developing model
    - Need flexibility to deal with multiple data types (limited ability to have specific data requirements)

- **Basic USFWS model (*Emily, Leslie, & Mark*)- 40 min.**
  - Discuss model assumptions (statistical and biological) and reasoning (*Leslie*)
    - Especially the assumptions highlighted recently (open population, etc.)
  - Show model (*Emily*)
  - Discuss priors (*Emily & Mark*)
  - Discuss data inputs and R code to run the model (*Emily, Leslie, & Mark*)

- **Walk-thru of smaller project (90 wind turbine) example (*Emily*)- 20 min.**
  - Demonstrate model approach and code inputs
  - Show changes /input changes as the result of changes in project design
  - Possibly walk through R code

- **Thousand Wind Turbine Project (*Nathan*)- 20 min.**
  - Data
    - truncated observation points to only include eagle observations within 800m
    - etc.
  - General Service approach
  - Model inputs/code

- **Remaining Questions and Answers (*All*)**

FWS Basic Eagle Collision Model:

Overview for Third Party Review

Background

- **The Bald and Golden Eagle Protection Act**
  - prohibits “take” of eagles without a permit (16 USC 668-668c)
  - Defines “take” to include “pursue, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb”
  - Prohibits take of individuals and their parts, nests, or eggs
  - Service expanded this definition by regulation to include the term “destroy” to ensure that “take” includes destruction of eagle nests.
  - “Disturb” is further defined by regulation as “to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause,….injury to an eagle, a decrease in productivity, or nest abandonment” (50 CFR 22.3).
- Assessment and authorization of “permitted take” must be consistent with BGEPA and subsequent regulations

Background

- **Eagle Permit Rule**
  - In 2009, FWS promulgated regulations to permit the unintentional take of eagles in the course of conducting otherwise lawful activities (Title 50 Code of Federal Regulations, Sec. 22.26)
  - FWS set take limits that it determined would be consistent with Congress's mandate in the BGEPA that any authorized take be consistent with the preservation of the bald and golden eagle.

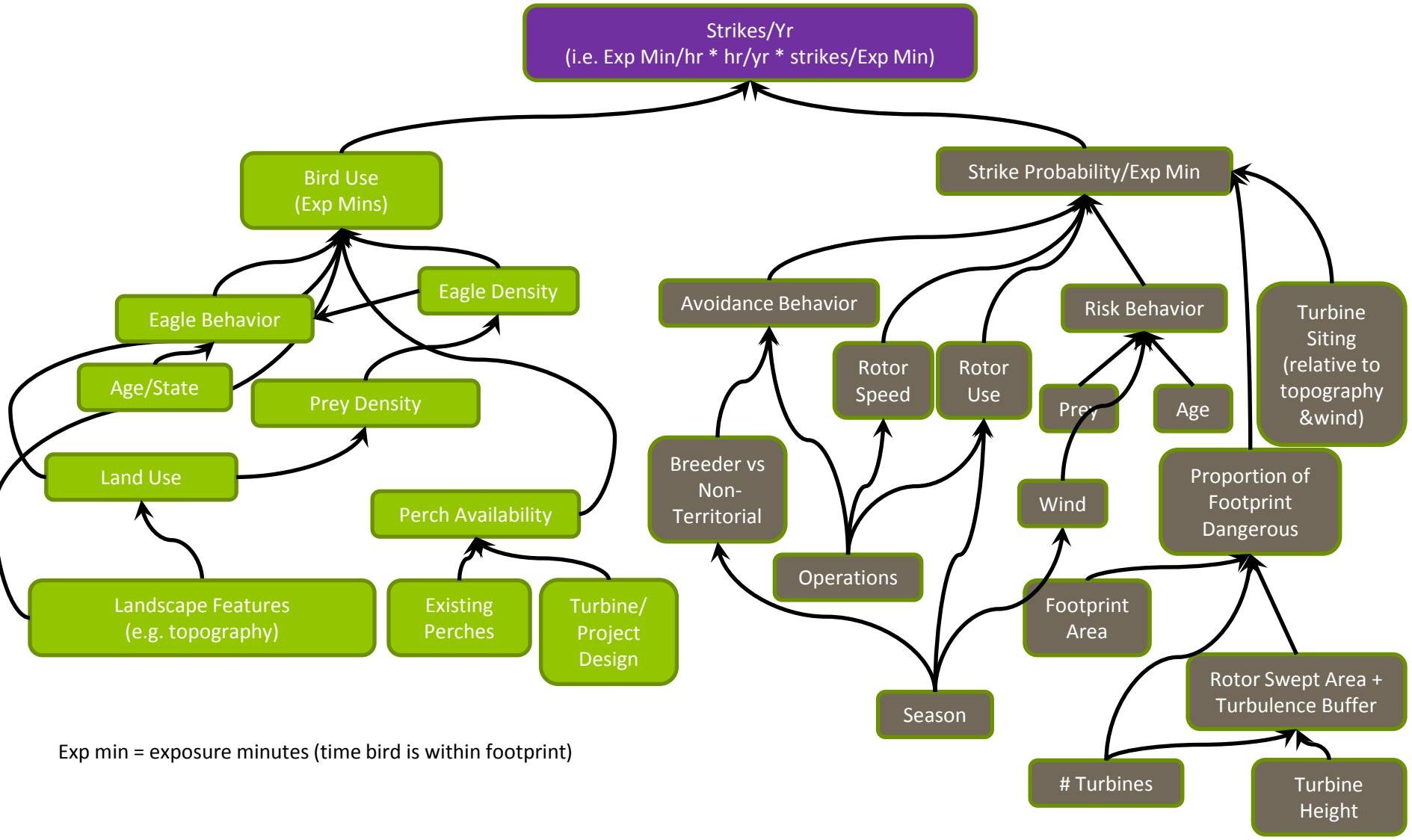
Background

- **Need for a Model to Predict Take**
  - FWS needed a mechanism to predict amount of take that might occur at facilities seeking incidental eagle take permits to ensure take did not exceed calculated safe levels
  - Because of the pressing need, FWS decided to develop programmatic permits for wind facilities first
  - There is substantial uncertainty in all aspects
    - Golden eagle population status
    - Population-level risk of wind mortality
    - Factors that influence risk
    - Ways of minimizing risk
  - Obvious candidate for formal adaptive management, and the fatality prediction model plays a key role in that process

Building a Model

- FWS Eagle Technical Assessment Team
  - Initially reviewed existing models for predicting take of eagles and other raptors at wind facilities
  - No existing model was strongly supported
  - The team decided to take elements of existing models and develop one specific for FWS's use
    - In that process the team considered many factors that
      - …Influence use of a site by eagles
      - …Were hypothesized to increase risk of a strike

Building a Model



Exp min = exposure minutes (time bird is within footprint)

- **contradictory and limited scientific support for many of these factors**

Building a Model

- As ETAT moved forward, FWS solicitors determined we were limited by the existing Eagle Permit Rule in terms of data we could require of prospective permittees
  - FWS cannot *require* collection of specific data or use of specific model given rule language, but can make recommendations
- We recognize that this imposes serious limitations
  - We wanted the ability to include data in meta-analyses to consider site-specific factors that may influence risk (consistency across sites) in an adaptive management context
  - Some concerns about levels of expertise of data collectors
- FWS will have the ability to fix this in a future rule revision, but for now we have accepted our model must be simple to accommodate the minimal data we typically have to work with for particular project

Basic FWS Model

Collision Fatalities =

Exposure Rate · Collision Probability · ε

(ε expands to all hazardous area & daylight hours)

$$F = \varepsilon \lambda C$$

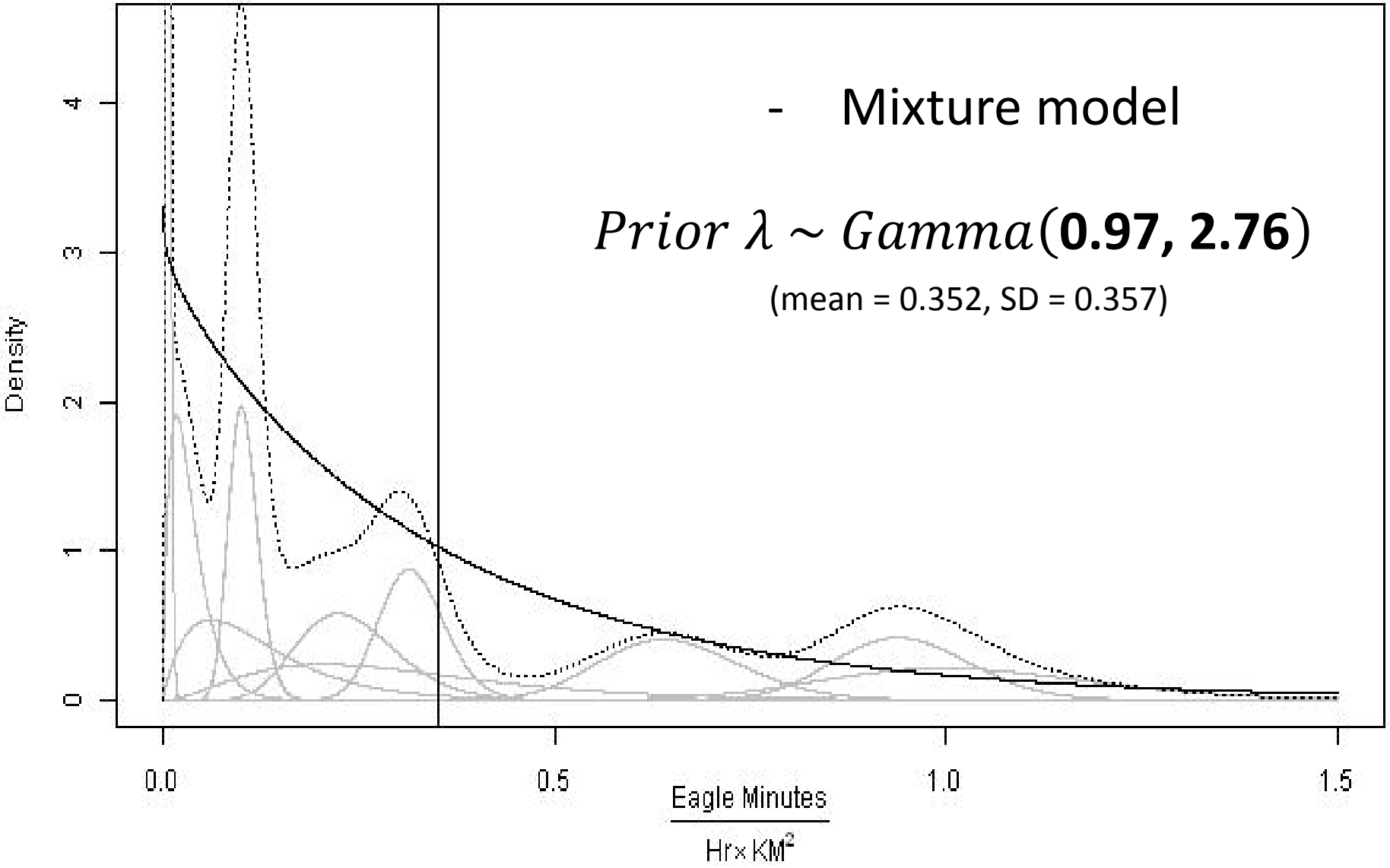
- F: eagle fatalities
- ε: hrs km^2
- λ: eagle min hrs^{-1} km^{-2}
- C: eagle fatalities|eagle min

Basic FWS Model

$$F = \varepsilon \lambda C$$

- Bayesian approach
- Priors for Exposure and Collision rates
  - Best available information
  - Needed to represents full range of potential future projects
- Update collision probability with post-construction mortality data
- Reasonable data collection expectations (eagle flight minutes in the project area)

Exposure Prior:



- Mixture model

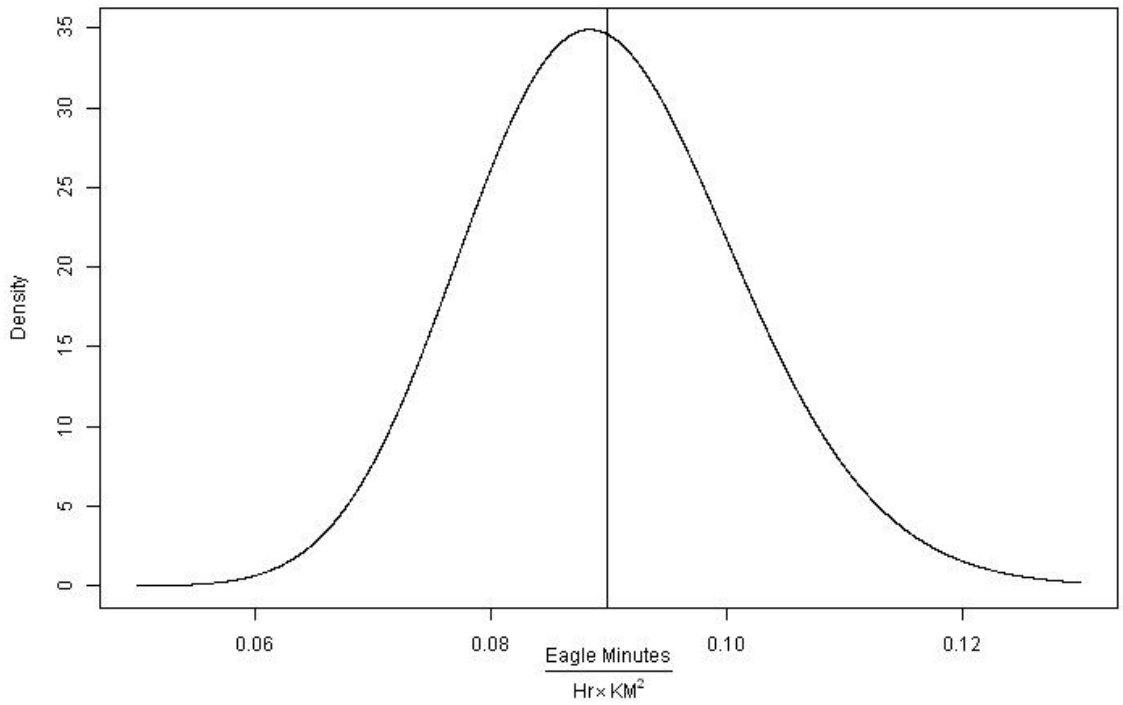
$$Prior\ \lambda \sim Gamma(\mathbf{0.97, 2.76})$$

(mean = 0.352, SD = 0.357)

Exposure Posterior

- observed eagle minutes follow a Poisson distribution with rate λ

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

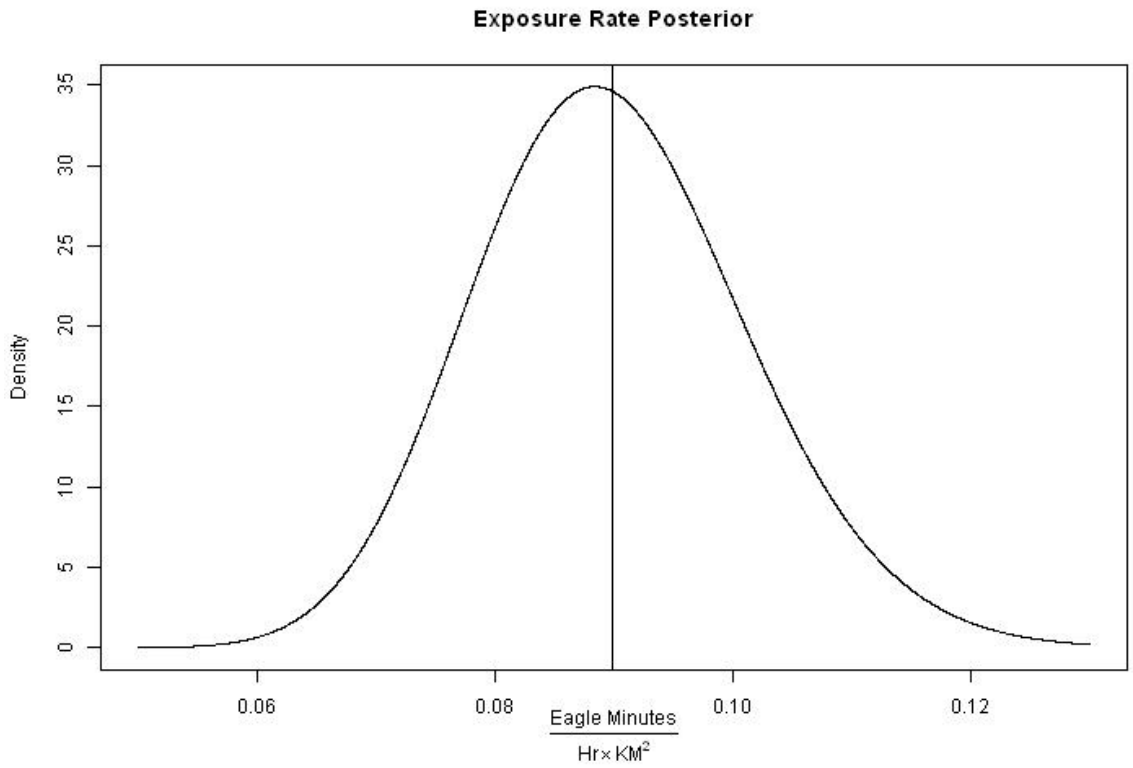


Exposure Posterior:

eagle minutes

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

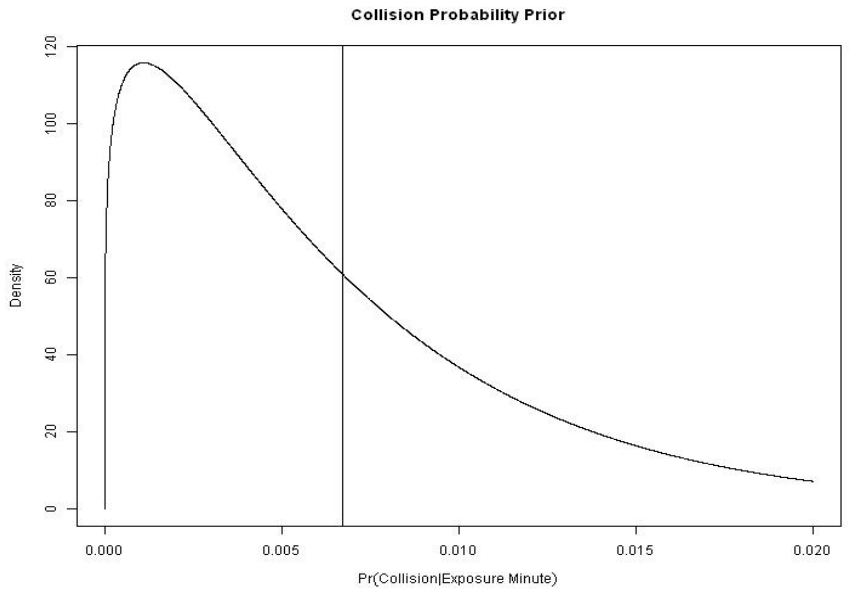
$km^2 \cdot hr$



Collision Prior:

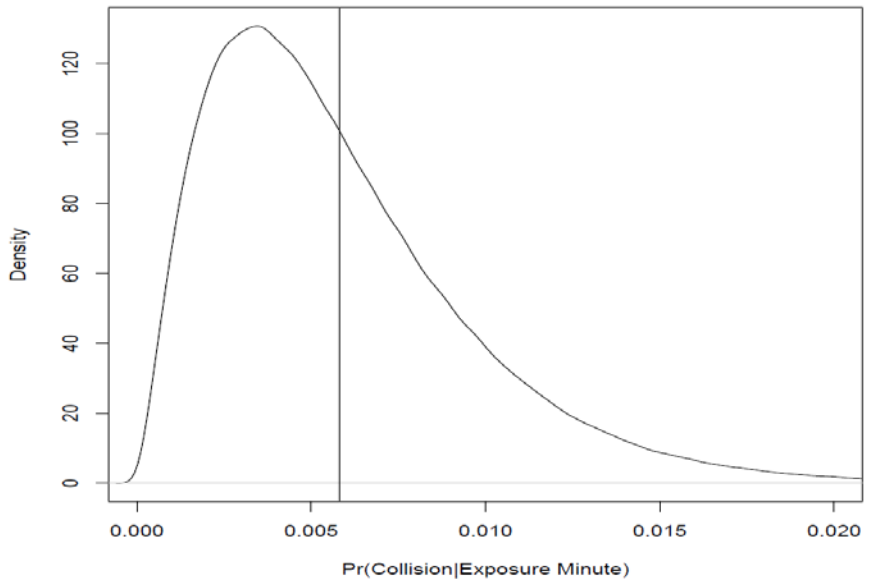
- Based on avoidance data from Whitfield 2009
  - Best publically available data
  - Weighted mean (used in examples presented & code default)
  - Mean of corrected avoidance
- Prior to be updated with mortality data

$$Prior\ C \sim Beta(1.2, 176.7)$$



(mean = 0.0067, SD = 0.0061)

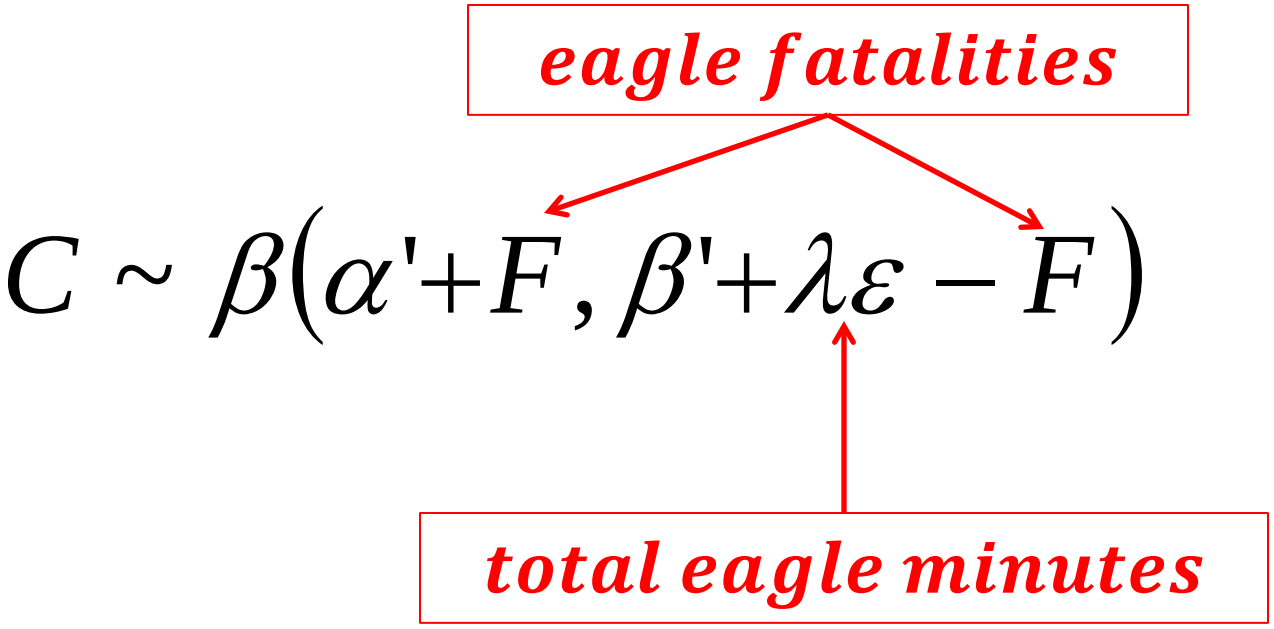
$$Prior\ C \sim Beta(2.3, 396.7)$$



(mean = 0.0058, SD = 0.0038)

Collision Posterior

- Assuming fatality data comes from binomial distribution with probability *C*



Expansion term

- Constant
- Hazardous area
  - based on turbine rotor size & # turbines
- Daylight hours
  - can be modified to reflect operational reality (time when turbines spinning, …) when supporting data area available

Assumptions

- Model Structure
  - Easily adaptable
- Core
  - Basic to the model

Model Structure

- Poisson distribution is appropriate to describe eagle minutes
  - Data may be over-dispersed
  - Switch to zero-inflated or over-dispersed Poisson

- Turbine operation
  - Only operational hours
  - Different types of turbines

$$\varepsilon = \pi n_t \pi r_t^2,$$

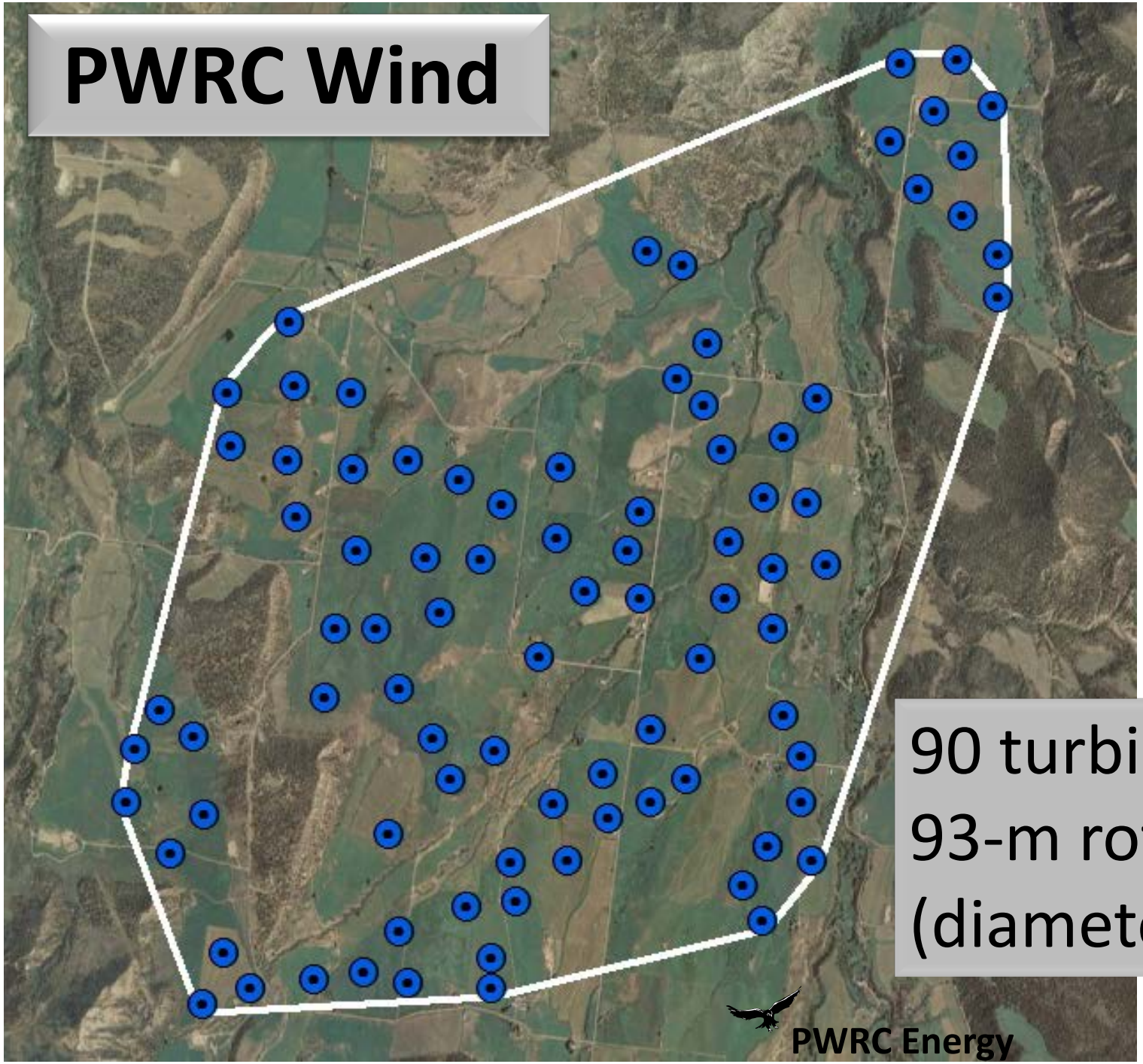
- Exposure is constant across the project site
  - Eagle use data are representative of general use (annually or by strata) of the project area
  - Temporal or spatial stratification can be incorporated

Core

- All collisions result in the eagle's removal from the population
- Eagles are only at risk of collision during daylight hours
- A relationship exists between pre-construction eagle exposure and subsequent fatalities, given the total hazardous area.
- Independence
  - Potential dependence negated by averaging to a single datum

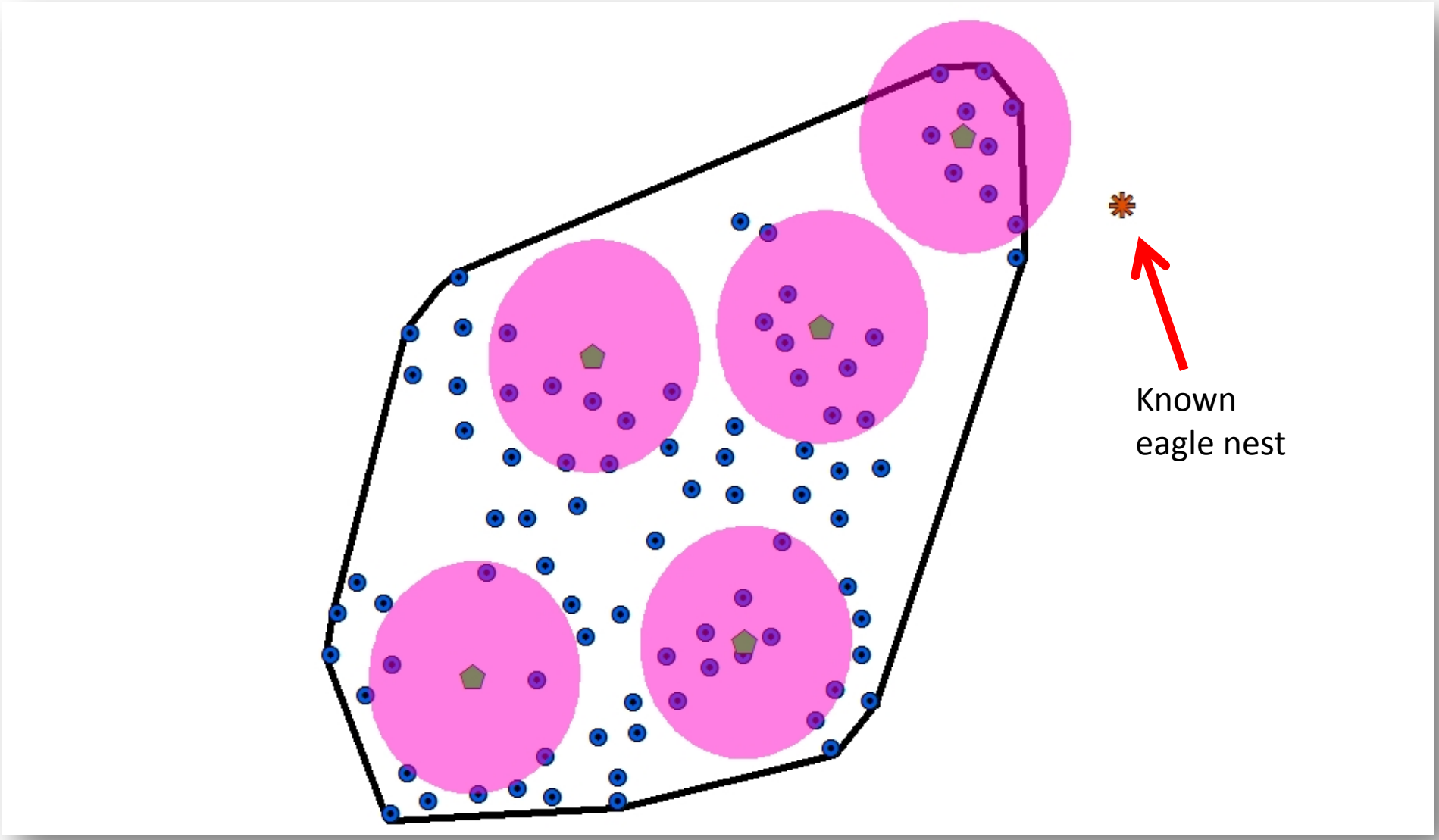
Core

- Open population
  - Eagles movement occurs over areas larger than the project footprint
- Collision probability prior is constant across time and individuals
  - Within strata, collision probability is constant
- Hazardous area
  - 0-200 m, collision probability is integrated across this space


PWRC Wind
90 turbines
93-m rotor
(diameter)
PWRC Energy

PWRC Energy

- Sampling:
- Potential turbine footprint = 19 km2
- 30% spatial coverage
  - ≈ 6 km2
  - ≥ 3 800-m radius count locations



PWRC Energy

PWRC Energy

Sampling:

- **Potential turbine footprint = 19 km^2**
- **≥ 30% spatial coverage**

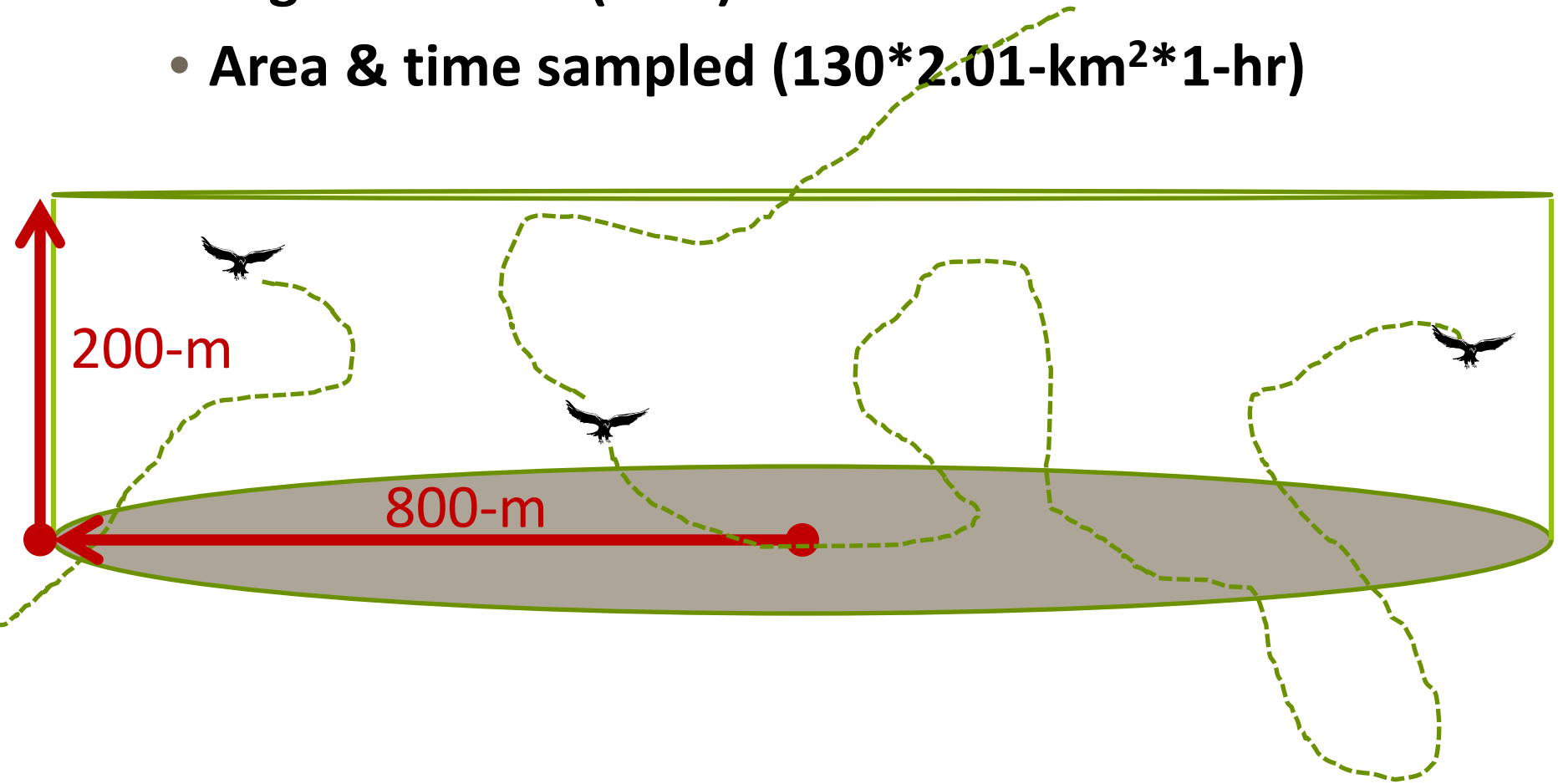
  ≈ 6 km^2

  ≥ 3 800-m radius count locations

  (added 2, to ensure representative coverage)
- **≥ 2 counts per month per point = 120 counts**
- **2 additional counts in spring = 130 counts total**

Eagle Minutes

- Circular plot counts (point counts)
  - Eagle Minutes (= 60)
  - Area & time sampled (130*2.01-km^2*1-hr)



Data Summary

- **60 eagle minutes observed**
  (> 30 % in NE corner)

- **130 1-hr counts (800-m circular plot)**
  261 km^2-hrs total

- **annual daylight hours = 4454**

Applying the Model

$$F = \varepsilon \lambda C$$

$$4454\ \text{hr} \cdot \pi \cdot n \cdot (0.0465\ \text{km})^2 = 2723\ \text{hr} \cdot \text{km}^2$$

Daylight

Hazardous Area

PWRC Power:

$$F = \varepsilon \lambda C$$

$$Posterior\ \lambda \sim Gamma(60.97, 263.76)$$

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

eagle minutes = 60

$km^2 \cdot hr = 261$

PWRC Power:

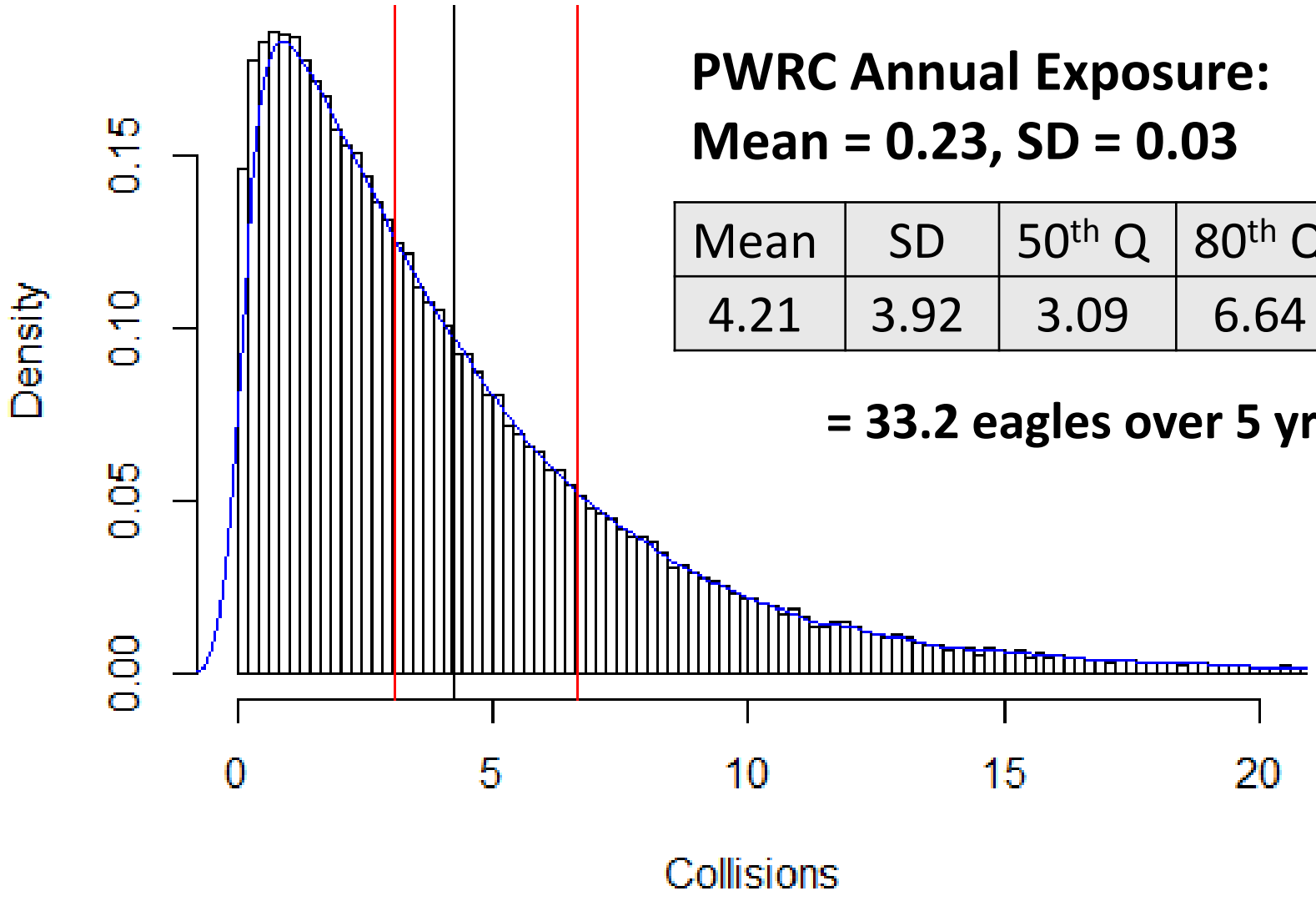
$$F = \varepsilon \lambda C$$

$$Prior\ C \sim Beta(1.2, 176.7)$$

- Initially, uses the prior (mean = 0.0067, SD = 0.0061)

- Updated with site-specific mortality data

Annual Collision Fatalities:



PWRC Annual Exposure:
Mean = 0.23, SD = 0.03

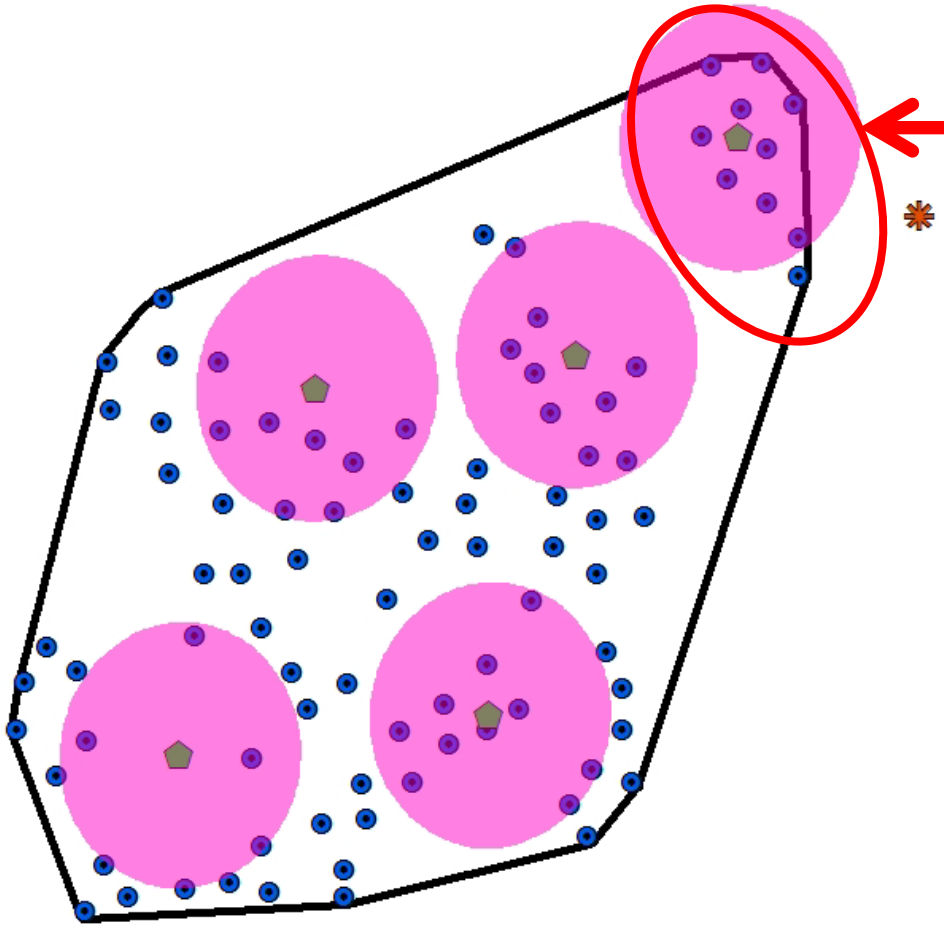
Mean	SD	50th Q	80th Q
4.21	3.92	3.09	6.64

= 33.2 eagles over 5 yrs

Data for modeling collisions

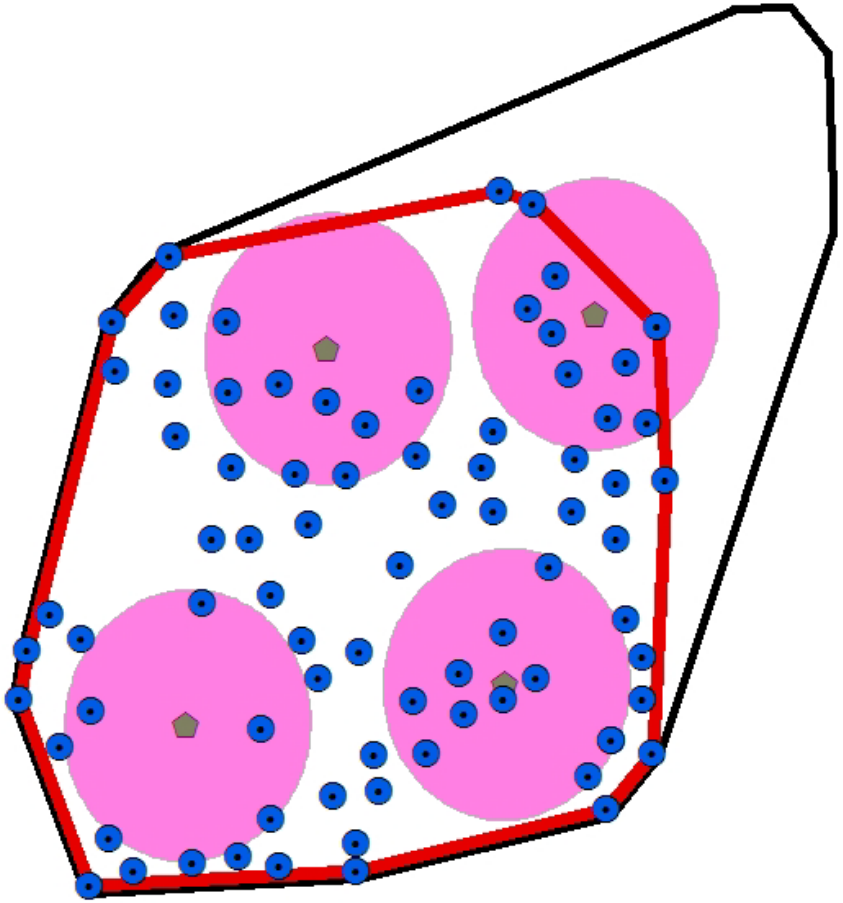
- # turbines
- turbine size
- eagle minutes observed
- time & area sampled
- stratification (if applicable)

Siting Adjustments



- Highest eagle use
- Flight path maps show frequent use within footprint
- PWRC Power opts to remove turbines & reduce project size

Siting Adjustments



Model inputs:

~~- 60 eagle mins~~

- 36 eagle mins

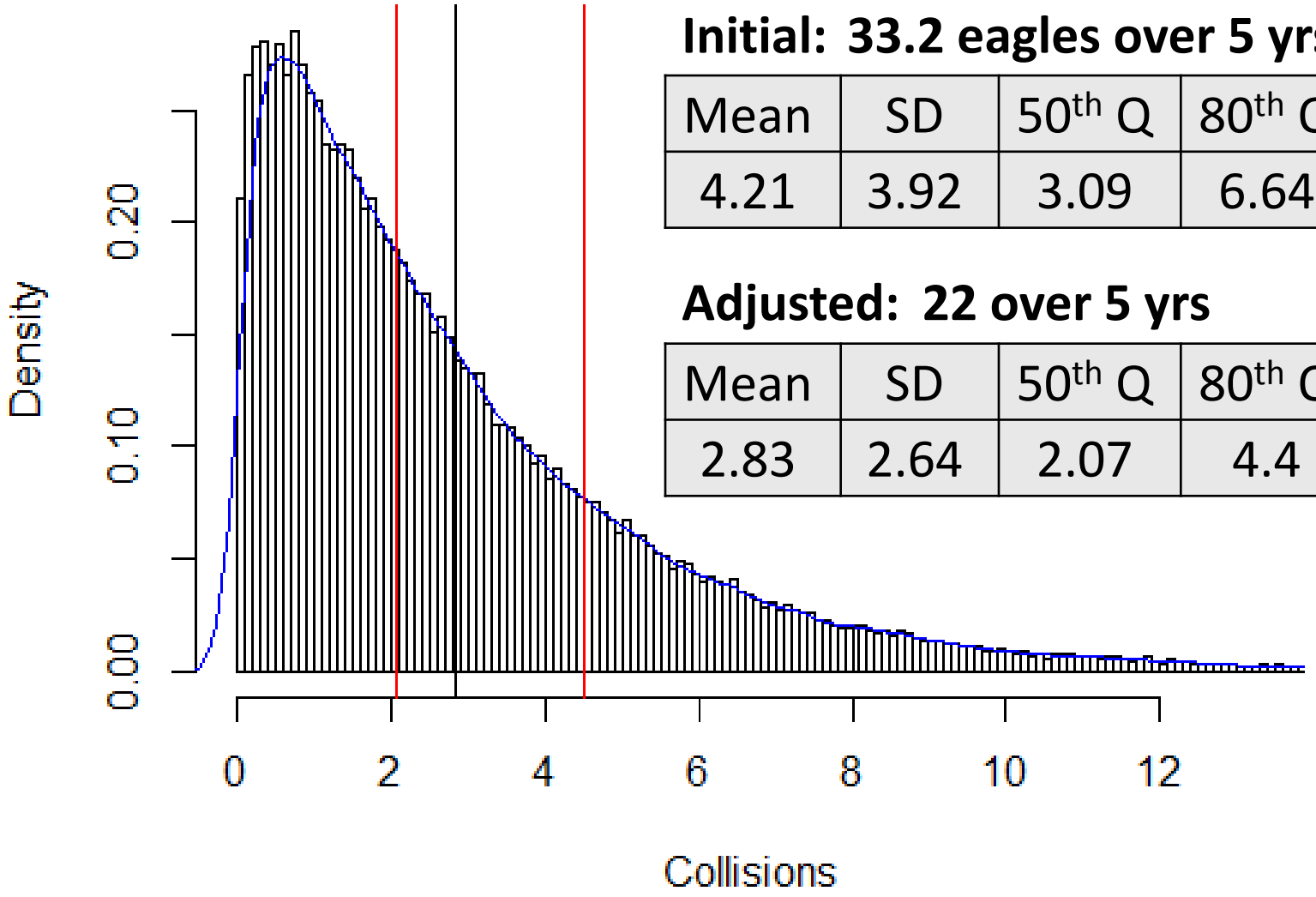
~~- 130 count hours~~

- 104 count hours

~~- 90 turbines~~

- 80 turbines

Adjusted Annual Collision Fatalities:



Initial: 33.2 eagles over 5 yrs

Mean	SD	50th Q	80th Q
4.21	3.92	3.09	6.64

Adjusted: 22 over 5 yrs

Mean	SD	50th Q	80th Q
2.83	2.64	2.07	4.4

Updating Fatality Estimates :

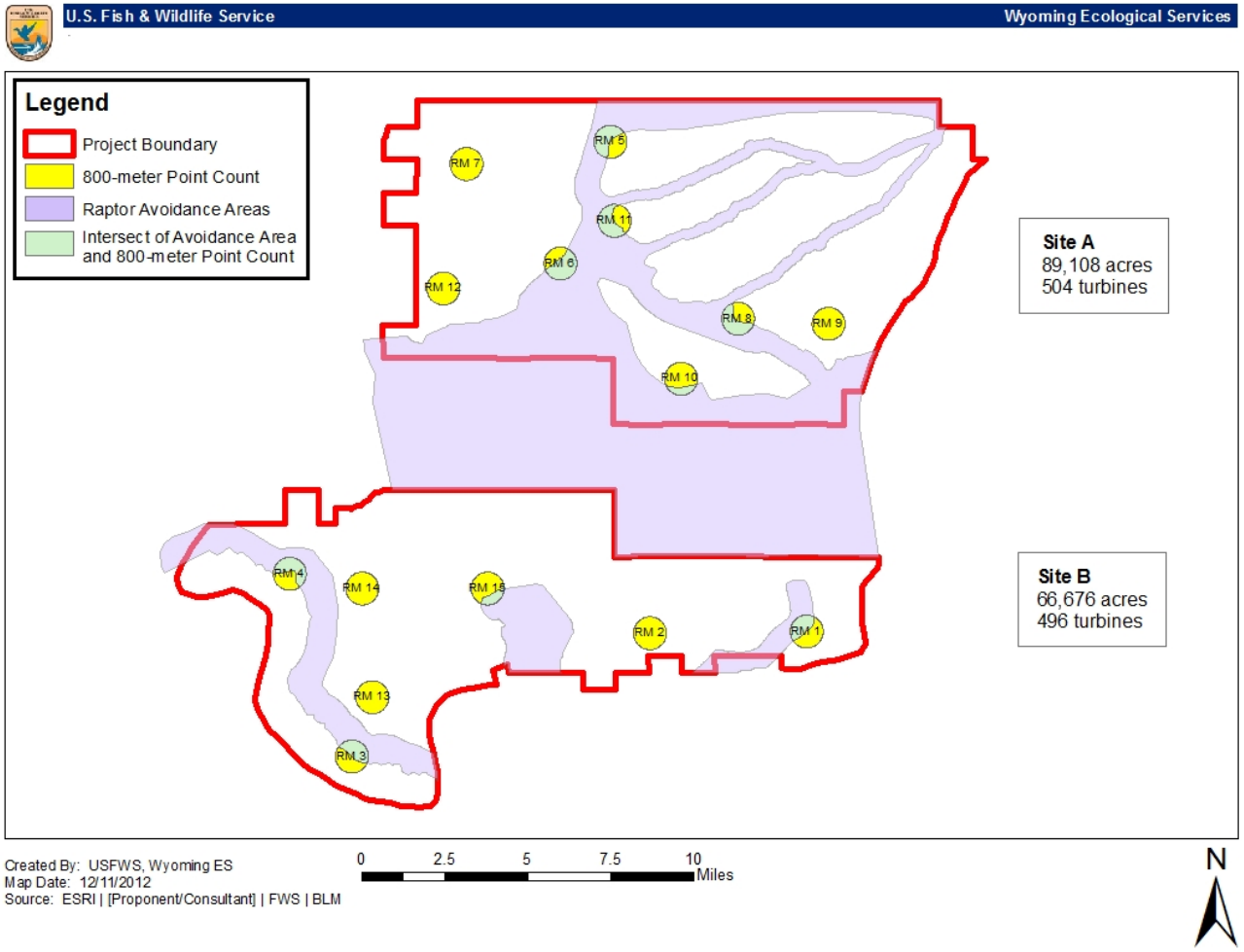
Pre-construction estimates:

	Mean	SD	2.5%	50%	80%
Collision Prob	0.0067	0.0062	0.0003	0.005	0.012
Ann Fatalities	2.8	2.66	0.1189	1.995	4.438
5-yr Fatalities	14.01	13.32	0.5945	9.973	22.19

Post-Construction adjustment, 10 carcasses found over 5 yrs:

	Mean	SD	2.5%	50%	80%
Collision Prob	0.00635	0.0014	0.0041	0.0062	0.00745
Ann Fatalities	2.52	0.342	2.04	2.47	2.79
5-yr Fatalities	12.63	1.71	10.2	12.37	13.95

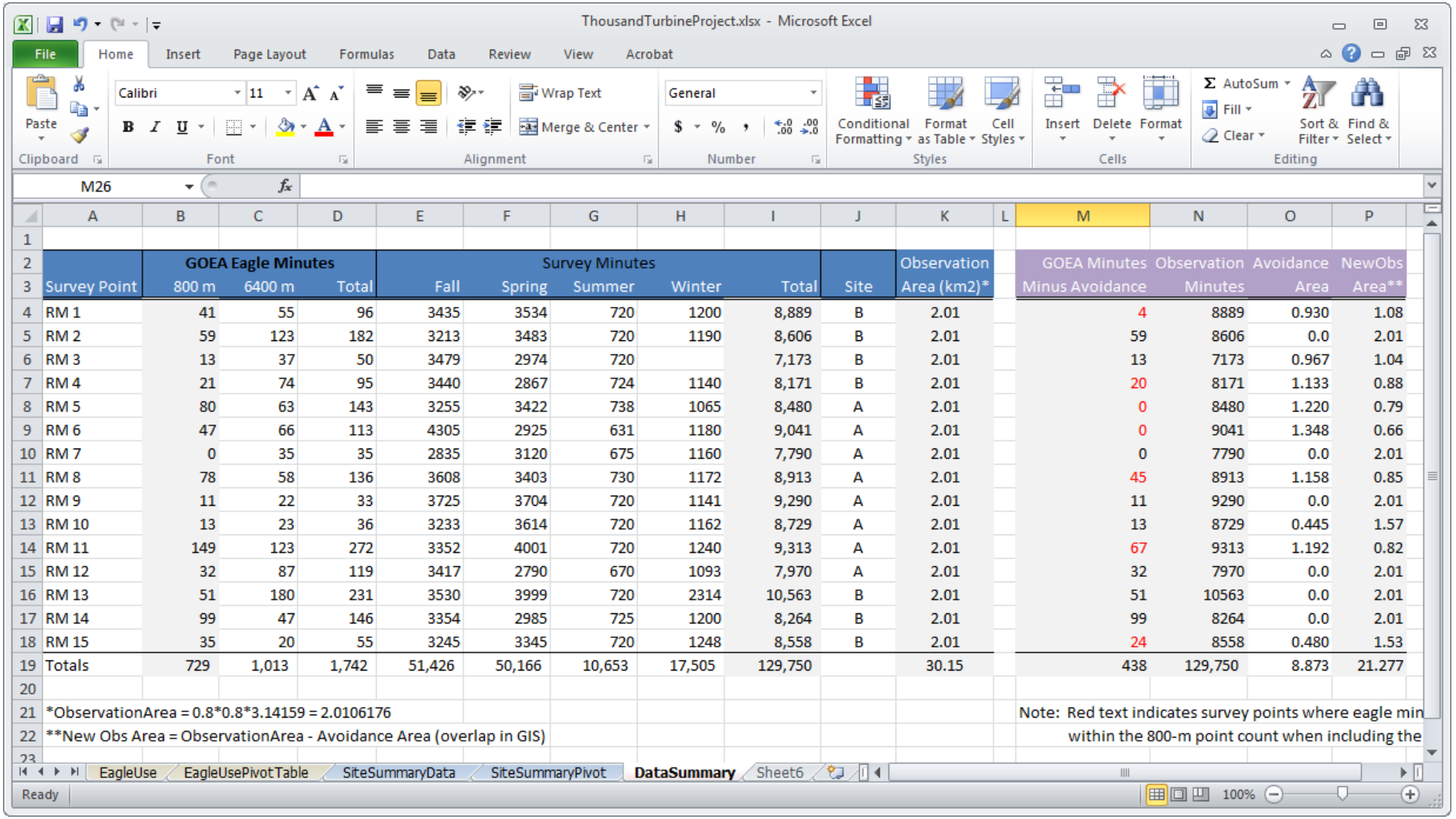
Thousand Turbine Project



Files for the TTP

- Map showing:
  - project boundary,
  - 800-m point count locations, and
  - proposed avoidance areas;
- Spreadsheet with raw and summarized data, including:
  - survey point number, date, species and age, survey minutes,
  - eagle flight minutes, distance to eagle, and total eagle minutes;
- Text file with model inputs and results; and
- Methods used by FWS to adjust eagle minutes and survey areas to account for the avoidance areas.

Raw and Summarized Data


ThousandTurbineProject.xlsx - Microsoft Excel

Survey Point	GOEA Eagle Minutes 800 m	GOEA Eagle Minutes 6400 m	GOEA Eagle Minutes Total	Survey Minutes Fall	Survey Minutes Spring	Survey Minutes Summer	Survey Minutes Winter	Survey Minutes Total	Site	Observation Area (km2)*	GOEA Minutes Minus Avoidance	Observation Minutes	Avoidance Area	NewObs Area**
RM 1	41	55	96	3435	3534	720	1200	8,889	B	2.01	4	8889	0.930	1.08
RM 2	59	123	182	3213	3483	720	1190	8,606	B	2.01	59	8606	0.0	2.01
RM 3	13	37	50	3479	2974	720		7,173	B	2.01	13	7173	0.967	1.04
RM 4	21	74	95	3440	2867	724	1140	8,171	B	2.01	20	8171	1.133	0.88
RM 5	80	63	143	3255	3422	738	1065	8,480	A	2.01	0	8480	1.220	0.79
RM 6	47	66	113	4305	2925	631	1180	9,041	A	2.01	0	9041	1.348	0.66
RM 7	0	35	35	2835	3120	675	1160	7,790	A	2.01	0	7790	0.0	2.01
RM 8	78	58	136	3608	3403	730	1172	8,913	A	2.01	45	8913	1.158	0.85
RM 9	11	22	33	3725	3704	720	1141	9,290	A	2.01	11	9290	0.0	2.01
RM 10	13	23	36	3233	3614	720	1162	8,729	A	2.01	13	8729	0.445	1.57
RM 11	149	123	272	3352	4001	720	1240	9,313	A	2.01	67	9313	1.192	0.82
RM 12	32	87	119	3417	2790	670	1093	7,970	A	2.01	32	7970	0.0	2.01
RM 13	51	180	231	3530	3999	720	2314	10,563	B	2.01	51	10563	0.0	2.01
RM 14	99	47	146	3354	2985	725	1200	8,264	B	2.01	99	8264	0.0	2.01
RM 15	35	20	55	3245	3345	720	1248	8,558	B	2.01	24	8558	0.480	1.53
Totals	729	1,013	1,742	51,426	50,166	10,653	17,505	129,750		30.15	438	129,750	8.873	21.277

*ObservationArea = 0.8*0.8*3.14159 = 2.0106176

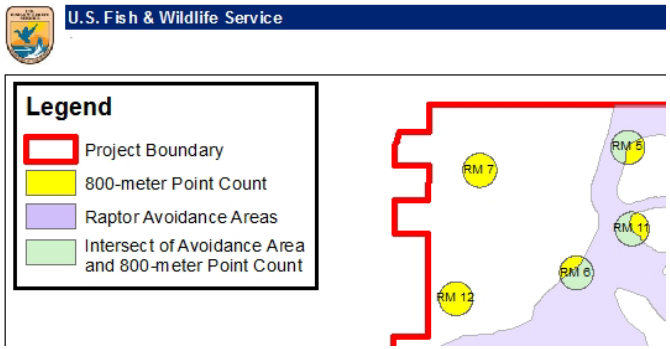
**New Obs Area = ObservationArea - Avoidance Area (overlap in GIS)

Note: Red text indicates survey points where eagle min
within the 800-m point count when including the

Accounting for Avoidance

- Eagle Minutes
  - Eagle minutes falling within the proposed avoidance areas were subtracted from the total eagle minutes.

- Area Surveyed
  - We subtracted the intersection (of the avoidance area with the 800-meter point count) from the point count area.
  - Because the model input is the point count radius, the radius was the average of the sum of the area for all point counts.



Data for the Fatality Model

Model Inputs	Initial without Avoidance	Adjusted with Avoidance
Number of Turbines	1,000	1,000
Turbine Size (diameter) (meters)	100	100
Daylight Hours (hours)*	4458 x 0.97	4458 x 0.97
Time Sampled (minutes)**	129,750	129,750
Eagle Flight Minutes <200 meters	729	438
Area Sampled (km)	30.15	21.28

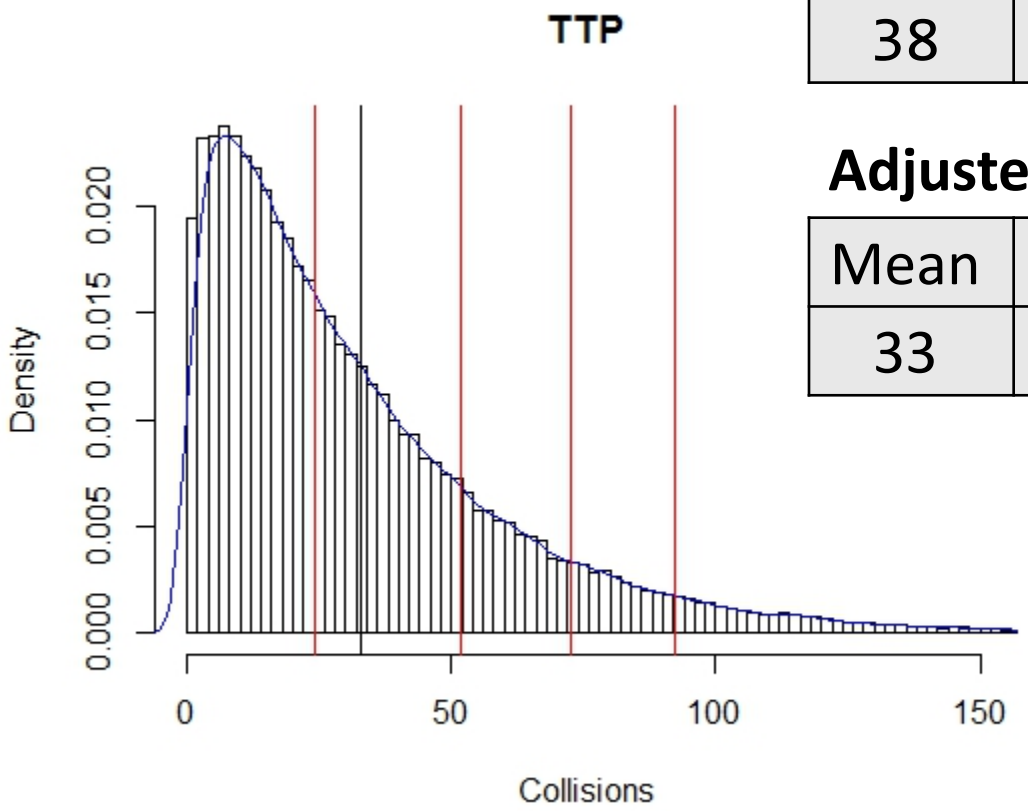
* “Daylight hours” is multiplied by 0.97, because meteorological data suggest turbines will not produce power during three percent of daylight hours.

** or 2,162.5 hours

Model Code (adjusted inputs)

- cProject<-"ThousandTurbineProject" #project ID to associate with model outputs
- nTurbine<-c(**1000**) #number of turbines
- HazRadKm<-c(**100**/2/1000) # hazardous area radius (kilometers); 100-m turbine
- HzKM2<-sum(nTurbine*pi*HazRadKm^2)
- CntHr<-c(60/60) # count duration (in hours)
- Days=c(365.25) # days to extrapolate a strata to (prediction)
- # should total 1 year for annual collision fatality estimate
- LtHrPerDay=c(**4458/Days*0.97**) # avg daylight hours per day for "Days" (previous line)
- # 0.97 assumes turbines are not spinning during 3 percent of daylight hours
- ## Create the "ExpSvy" data frame
- # this includes the Eagle Minutes observed, number of counts conducted,
- # and the area observed at each observation point
- ExpSvy<-data.frame(row.names=c("TTP"),
- EMin=c(**438**),
- nCnt=c(**2162.5**), # total obs min for all points=129,750 (129750/60=2162.5)
- CntKM2=c(pi*(**672**/1000)^2), # average radius for 21.277 km2 for 15 points
- DayLtHr=c(Days*LtHrPerDay)
-)
- AddTot<-FALSE #Add strata for total (TRUE) or not (FALSE)

Estimated Annual Collision Fatalities:



Initial: 300 eagles over 5 yrs

Mean	SD	50th Q	80th Q
38	35	28	60

Adjusted: 260 over 5 yrs

Mean	SD	50th Q	80th Q
33	30	24	52

Code

```
simFatalCPr <- function(EMin, EOutMin, SmpHrKM2, ExpFac, aPriExp=0.97,   bPriExp=2.76,aPriCPr=1.2, bPriCPr=176.7){

require(rv)

# Update the exposure prior
 if(EMin>=0){
   aPostExp <- aPriExp + EMin
   bPostExp <- bPriExp + SmpHrKM2
  }else{
   aPostExp <- aPriExp
   bPostExp <- bPriExp}

Exp <- rvgamma(n=1, aPostExp, bPostExp)

# Update the collisions prior
 if(EOutMin>=0){
  aPostCPr <- aPriCPr + EOutMin
  bPostCPr <- ((rvmean(Exp) * ExpFac) - EOutMin) + bPriCPr
 }else{
  aPostCPr <- aPriCPr
  bPostCPr <- bPriCPr}

 CPr <- rvbeta(n=1, aPostCPr, bPostCPr)

 Fatalities           <- ExpFac * Exp * CPr
 attr(Fatalities,"Exp") <- c(Mean=rvmean(Exp), SD=rvsd(Exp))
 attr(Fatalities,"CPr") <- c(Mean=rvmean(CPr), SD=rvsd(CPr))

 return(Fatalities)}
```

Third Party Review of U.S. Fish and Wildlife Service (Service)
Eagle Collision Model Webinar
18 January 2013

The US Fish and Wildlife Service hosted a webinar for participants in the third party peer review of the Eagle Collision Model used for estimating fatalities associated with wind energy projects. The webinar occurred on 18 January 2013 from approximately 1240h to 1415h Mountain Standard Time.

The **purpose** of this meeting was to review the background for the peer review, the construction and rationale for the existing model, and the two example projects.

ATTENDEES:

Service
- Matt Hogan
- Clint Riley
- Casey Stemler
- Kevin Kritz
- Brian Millsap
- Emily Bjerre
- Mark Otto
- Mark Sattelberg
- Nathan Darnall
- Patricia Sweanor

USGS Leslie New

Panelists
- Bryan Bedrosian
- Todd Katzner
- Tim Keitt
- Carl Schwarz

AMEC
- Dawn Johnson
- Matt Evans
- Megan Hazell
- Melissa Greulich

Background

- Brian Millsap provided the background for the peer review, specifically the reason for creating the Service model to assess eagle mortality risk from wind turbines.
- The Bald and Golden Eagle Protection Act (BGEPA) is the basis for protection of golden eagle (GOEA) and bald eagle (BAEA). Prior to 2009, taking of either eagle species was prohibited unless someone had a permit for purposeful take. Through the BGEPA regulations finalized by the USFWS in 2009, permits are now available for non-purposeful take (i.e., incidental take, where the take occurs incidental to other legal activities, the purpose of which was not to take eagles) of both eagle species. Any take has to be consistent with the goal of maintaining stable or increasing populations of both GOEAs and BAEAs.
- The model is needed to predict the level of take of eagles prior to issuing permits to ensure take does not exceed calculated safe levels. Model is generally risk adverse and conservative due to the uncertainties. Wind energy is the first industry for which the Service has developed a model to support the permitting process for wind energy projects. The model and the process behind it is meant to be adaptive and build new knowledge into it to aid the Service permitting process.
- Many hurdles in creating the model, foremost is uncertainty in (see slides):
  - GOEA population status
  - Population level risk of wind mortality
  - Factors that influence risk
  - Ways of minimizing risk
- Model building

    - Many elements already existed so a team of experts (from the Service, USGS and other federal and state agencies) was assembled to develop the model.
    - Model is limited/simple due to the lack of data.
- Other limitations: the Service cannot require a permittee to collect any specific data or to use a specific protocol for collecting data; the Service can only make recommendations.
- Question: It would be useful to know more about the context of the review. Answer: There is a draft template for you review which includes the questions from the Statement of Work (SOW), this will be finalized after the webinar and distributed to all reviewers.

Model Development

- Leslie New provided a summary of model development.
- Simple model with basically 3 factors. Basic model equation is "Collision fatalities" = Exposure rate*Collision Probability*Expansion Factor.
- Bayesian model was chosen because the lack of data and amount of uncertainty can be incorporated. Interpretation of the results is also often easier than with other techniques.
- Exposure prior was based on 11 facilities/projects using a mixture model.
- Question: Is there one exposure distribution for every season? Answer: Prior exposure is set but the posterior exposure can change by season.
- Collision Prior: Most controversial part of model. It uses best available public data for avoidance from Whitfield 2009. The Service is considering using a weighted mean. The Service intends to adjust this prior once better data is available.
- Collision Posterior: Assumes fatality data comes from binomial distribution with probability C and assumes fatalities are known. There is currently a USGS project to estimate fatality at wind turbine facilities.
- Expansion Factor: Based on turbine rotor size, # turbines, and daylight hours. Operational hours can be variable depending on the facility and may be different than daylight hours.
- Model Structure Assumptions:
    - Eagle-Minutes: Poisson distribution is assumed. This may be zero inflated or over-dispersed, which would require a different approach to model fitting.
    - Operational hours: known/expected turbine operation can be easily modified for the model, different types of turbines (i.e., varying radii) can be included by separating out terms in equation.
    - Exposure (posterior): assumed to be constant across the project site, but can be stratified geographically and/or seasonally.
- Core Assumptions (see slides):
    - Assumed all collisions result in fatality/remove eagle from the population.
    - Eagles are only at risk during daylight.
    - There is a relationship between preconstruction exposure and fatalities in an area.
    - There is immigration and emigration of eagles, therefore an open population of eagles. This assumes there is replacement of existing eagles if one leaves or dies.
    - Collision probability is constant within strata.
    - Hazard area is around the wind turbine blades and within the site from 0 – 200 meters altitude. 200 meters allow for consistent definition of the hazard area across sites.

- All files for the models are on the FTP site for this project.

90 Turbine Example

- Emily Bjerre provided a summary of the smaller example project for the model runs. The example is a 90 turbine, 93 m turbine-rotor diameter fictional project. The data collected on the project site and how it should be input into the model was described.
    - 80^{th} quantile is the number of collisions that would be used to permit fatalities at a specified project.
    - Estimated values from field data collected in the first year. This prediction was then used then for the next 5 years.
- Question: Are permits issued on an annual basis or other time period? Answer: Take is estimated annually but permits are issued for a 5 year time period.
- Question: If you add the 80^{th} percentile 5 times it will not be representative of the 5 years a permit is valid because each year is independent. Answer: The way our model is set up right now, the 80^{th} percentile will be the same because the same estimate will be created for each year. Permits are issued for a total number of eagles for 5 years. Follow up: If you have an exposure survey with a wide variation of estimates, the distribution would be much more spread out and the 80^{th} percentile would be larger.
- Question: in the assumptions, one eagle-minute is equal to any other equal-minute, but in reality 60 different eagles adding up to 60 eagle-minutes is different than 1 eagle for 60 eagle-minutes. More fatalities are likely with more eagles flying. Answer: The Service did generalize, but it is meant to be an average and represent how eagles will use a particular site. If an eagle enters an area repeatedly, it has a high risk of getting struck, but the open population idea assumes replacement will occur. On average, the two situations should even out because of the replacement assumption.
- Question: What are the placement properties for wind turbines? Answer: There are operational/efficiency considerations on where they can be placed, how close to one another they may be, placement on ledges, etc. There is no general rule, dependent upon environment. Follow up: Placement will vary with size of turbine. Larger ones will greatly change airflow. Follow up Question: What about height? Answer: That can vary due to site conditions and turbine mix at a site.
- Question: Is pre-construction data for only one year or more than one year? Answer: The Service recommends more than one year, but not all permittees collect this data for more than one year.
- Question: Is there a way to work with multi-year data? Answer: The model is made to use previous year data but multiple years data is recommended.
- Question: Why aren't fatalities a whole number? Why wouldn't you want your mean to 10 carcasses for this example? Answer: The mean of a binomial need not be an integer.
- Question: Why does the data show higher estimates of fatalities than those observed? Answer: When you correct for assumed observer error and observation delays, the total number of estimated carcasses is higher than the actual number found. It is assumed that the carcasses are found in the first place and that they last long enough for someone to find them.

1000 Turbine Example

- Nathan Darnall described another example project that is proposed for construction in Wyoming with 1000 turbines.
    - Accounting for avoidance – where 800 m count area and avoidance area overlap – subtracted out the eagle minutes and the area in the model. This occurred because there is no chance of a wind turbine being built in the eagle avoidance areas.
    - The survey areas identified are not random, but selected based on eagle habitat and good potential for eagle observation and spatially balanced.
- Question: How do you define what constitutes daylight hours? Answer: A program in NOAA that defines sunrise and sunsets. Any comments that would be representative for eagles are welcome.
- Question: What are raptor avoidance areas? Answer: Areas identified by the consultant that are "high eagle use" that should be avoided by the developer. Sometimes based on topographical features.
- Question: How do they determine the project area where all the turbines will be built? Answer: A range of projects come in, some will come in before construction asking if the area is good for wind turbines, some will already be constructing and then determine areas within the identified area. Also, some will look for areas that potentially harvest the most wind and then amend the plan.
- It is important to note that the Service assumes that the eagle use data collected are representative of the project site.

Questions going forward – send to Dawn Johnson (dawn.johnson@amec.com) and she will coordinate answers and distribute to all panelists.