

Appendix C

*Bayesian Eagle Risk Analysis and Fatality Prediction
for the Horse Butte Wind Project*

Appendix C

Bayesian Eagle Risk Analysis and Fatality Prediction for the Horse Butte Wind Project

C.1 Background

The U.S. Fish & Wildlife Service (Service) uses explicit models in a Bayesian statistical framework to predict eagle fatalities at wind facilities while accounting for uncertainty. The analysis presented below follows the Service's Eagle Conservation Plan Guidance (ECPG) Version 2 (USFWS 2013); a more detailed background on the Service's model and modelling framework are presented in Appendix D of the ECPG.

The Service fatality prediction model assumes that there is a predictable relationship between pre-construction eagle exposure events (λ ; eagle-minutes below 200 meters / hour·km²) and subsequent annual fatalities resulting from collisions with wind turbines (F), such that:

$$F = \varepsilon \lambda C$$

where C is the probability of a collision given one minute of eagle flight within the hazardous area (see definition in the ECPG technical appendices), and ε is the expansion factor, a constant that describes the total area (or volume) and time within a project footprint that is potentially hazardous to eagles. This is used to expand λC , the number of birds killed per minute of exposure, into the annual number of predicted fatalities.

One advantage of using a Bayesian modelling framework is the ability to incorporate existing knowledge directly into the model by defining an appropriate prior probability distribution (hereafter "prior"). The Service has defined a prior distribution for eagle exposure (*Gamma* (0.97, 2.76)) based on the exposure rates across a range of projects under Service review and others described with sufficient detail in Whitfield (2009) and has defined a prior for collision probability (*Beta* (2.31, 396.69)) based on information from projects presented in Whitfield (2009). These prior distributions are then updated with the data collected from the wind facility under consideration to obtain posterior distributions (hereafter "posterior") that provide the project specific estimates of λ and C . Specifically, the exposure prior can be updated with pre-construction eagle use data collected at a site (note: when adequate pre-construction survey efforts are performed, the relative influence of the λ prior distribution on the resulting posterior λ becomes negligible). The collision probability prior can also be updated with post-construction fatality estimates if/when a project becomes operational.

C.2 Calculating Model Variables

Exposure Rate Calculation (λ)

The exposure rate (λ) is defined in Appendix D of the ECPG as the number of exposure events (eagle-minutes) per daylight hour per square kilometer. Generally, site-specific

exposure values are determined by pre-construction surveys of eagle use; however, if these data are not collected, the exposure prior can still be used to predict fatalities. The exposure prior is defined in the ECPG as:

$$\text{Prior } \lambda \sim \text{Gamma}(0.97, 2.76)$$

This prior assumes that the eagle use surveys collected data on the eagles flying between 0–200 meters above ground level. However, because many projects were constructed, or their pre-construction data collection completed, prior to the publication of the ECPG, pre-construction eagle survey methods are not always consistent with this assumption, which is laid out in the Service’s recommendations in the ECPG. Exposure values calculated from data born from these surveys, especially where the 200-meter survey height was not achieved, may not be appropriate for use with the exposure prior as defined in the ECPG. However, deviations from the recommended survey height (i.e. survey ceilings less than or greater than 200 meters, or data only collected within a rotor-swept zone) can be accounted for by re-defining the exposure rate as the number of exposure events per daylight hour per volume (km³), instead of square kilometer. When running the model with this three-dimensional exposure value, the exposure prior must also be adjusted as below:

$$\text{Volumetric Prior } \lambda \sim \text{Gamma}(0.968, 0.552)$$

For projects that performed surveys at the recommended 200-meter survey height, or that did not perform surveys at all (i.e. only exposure priors were used in modelling), it matters not which of the above priors are used in modelling, as the model outputs are the same. However, where the range of heights surveyed was not 0–200 meters, the volumetric prior should be used to account for this difference (see Attachments 2 and 3).

Collection of eagle-use information at Horse Butte Wind Project (Project) did not begin until December 11, 2011. Since construction of the project had already begun by this time, no pre-construction eagle-use information was collected at this project. Consequently, no data are available to obtain a posterior distribution on λ , so the prior distribution on exposure is used to predict eagle fatalities for both golden and bald eagles at the Project. Modelling for the Project was done using the volumetric prior distribution described above.

Expansion Factor Calculation (ϵ)

Since the volumetric prior is being used, the expansion factor must also account for volume (of hazardous area). Thus, in Project model runs, the exposure factor is defined as the product of the total hazardous volume ($A = \pi \cdot r^2 \cdot h$, where r is the turbine rotor radius, h is 200 meters, and A is summed across all turbines) and daylight hours. The units for ϵ are hour·km³. The number of daylight hours observed annually at the project is 4,461 hours.

For this modelling effort, we will adjust the expansion factor to account for the approximate number of daylight hours that turbines were not operating because of low wind speeds (i.e. feathered out when wind speeds were below the factory cut-in speed of three meters per second). This project-specific adjustment is made based on an independent assessment of Project turbine operations by VBar, LLC (V-Bar). V-Bar used U.S. Navy daily sunrise-sunset data and individual turbine 10-minute operational records at the Project from September 2012 to November 2014 to count the mean monthly daytime operational hours for each turbine. The individual turbine data were corrected upward, based on downtime ratios to adjacent representative turbines, to account for their one-time repair events (foundation and blade repair) during the period assessed. The final count is an estimate of

the daytime idle hours that occur with the turbine's standard cut-in speed of 3 meters per second (mps). During daylight hours where turbines blades are feathered out and turbines are not spinning, we assume that there is negligible risk to eagles and modify the expansion factor in the model accordingly.

The following expansion factor, adjusted for estimated total time turbines are idle at the project each year because of their 3m/s cut-in speed, is used for both golden and bald eagles.

$$\varepsilon = (\pi \cdot (0.050^2) \cdot 0.200) \cdot ((32 \cdot 4460.877) - 28465) = 179.515 \text{ hour} \cdot \text{km}^3$$

Collision Probability Calculation (C)

The probability of collision (C) is the probability of an eagle colliding with a turbine for each minute of exposure (eagle-minutes in the hazardous area). The collision probability prior distribution is defined in Appendix D of the ECPG as:

$$\text{Prior } C \sim \text{Beta}(2.31, 396.69)$$

After construction, site-specific estimates of fatalities, based on post-construction fatality monitoring, can be used to update the collision probability prior. The posterior distribution (after updating the prior) is defined as:

$$\text{Posterior } C \sim \text{Beta}(2.31 + f, 396.69 + g)$$

where f is the number of fatalities estimated to have actually occurred at the project and g is the estimated number of exposure events that did not result in a fatality. Once determined, this posterior distribution can be used in the model to generate a fatality prediction and/or can serve as a new prior for subsequent updates as new post-construction fatality monitoring data is collected and fatality estimates derived.

Three years of post-construction fatality monitoring data were collected at the Project. Two updates to the collision probability were performed for each species using two site-specific fatality estimates (two estimates were needed because the post-construction monitoring method was altered between Years 1 and 2). The estimates used for each collision probability update are listed in Table 1. Inputs and bias trial data files used in the creation of these estimates are provided in Attachment 1 to this appendix. The “proportion of the turbine area searched” was estimated for use in the Service’s fatalityCMR (FCMR) software using Table 5 in Hull and Muir (2010). The FCMR software and details on the FCMR estimator can be downloaded online at <https://www.mbr-pwrc.usgs.gov/software/fatalityCMR.shtml>.

Table 1. Summary of Post-Construction Fatality Monitoring Efforts and Resulting Eagle Fatality Estimates

Year(s)	Dates	Turbines Searched	Search Plot Dimensions	Search Frequency	GOEA Carcasses Found	BAEA Carcasses Found	GOEA Annual Fatality Estimate ^(a)	BAEA Annual Fatality Estimate ^(a)
1	2012	10	126m x 126m	Biweekly	0	0	0.14	0.14
2 & 3	2013-2014	10	134m x 134m	Weekly Biweekly ^(b)	2 ^(c)	0	4.71	0.04

a. Estimates account for biases from imperfect searcher efficiency, unsearched areas, and carcass removal rates – site-specific data on these biases were collected during Years 1 and 2. See Attachment 1 for more details.

b. During Years 2 and 3, searches were performed weekly during spring (March 16 – May 15) and fall (August 16 – November 15), and bi-weekly during the rest of the year.

c. One of the two GOEA carcasses was discovered incidentally, but it was within a plot due to be searched five days from the date of the incidental discovery. Conservative assumption was made that the carcass would have remained for five days and would have been detected by searchers during the next scheduled search.

Note: GOEA = golden eagle; BAEA = bald eagle

The fatality estimate from Year 1 of post-construction monitoring was used to update the collision probability prior. Since this estimate was the same for both species (no carcasses found of either species during year 1), the first collision probability update was the same for both species. This update resulted in a collision probability distribution (Posterior C1) for both species of:

$$\text{Posterior } C1 \sim \text{Beta}(2.44, 709.42)$$

Next, the estimate from Years 2 and 3 of post-construction monitoring was used to further update Posterior C1. Since this estimate was different for each species, different collision probability posteriors (Posterior C2) resulted for each species as follows:

Golden Eagle

$$\text{Posterior } C2 \sim \text{Beta}(7.17, 1022.40)$$

Bald Eagle

$$\text{Posterior } C2 \sim \text{Beta}(2.48, 1023.55)$$

These posteriors (Posterior C2 for each species) were used in the final model run (see Section C.4). Posterior C2 can/will be further updated in the future as additional years of post-construction monitoring are performed. The R-code for updating the collision probability prior and Posterior C1 is provided in Attachment 2 of this appendix.

C.3 Bayesian Model Inputs and Calculations

Tables 2 and 3, below, summarize the model inputs for each species. The associated R-code is presented in Attachment 3 to this appendix.

Table 2. Summary of Inputs for Predicting Annual Golden Eagle Fatalities Under All Model Scenarios

Inputs		Notes
Approximate Location (GPS)	Lat: 43.40261 Long: -111.73753	
# of Turbines	32	Maximum proposed
Rotor Swept Radius	0.050 km	50-meter radius
Count Duration	0.333 hours	20 minutes
Count Cylinder Vol	0.402 km ³	800-meter radius, 200-meter height
Daylight Hours	28,465 ^(a) hours	Adjustment to total turbine daylight hours
Eagle Minutes	0	No pre-construction surveys
Number of Counts	0	No pre-construction surveys
Collision Prob. Prior	Beta (7.17, 1022.40)	Collision Posterior C2 (see above)

Table 3. Summary of Inputs for Predicting Annual Bald Eagle Fatalities Under All Model Scenarios

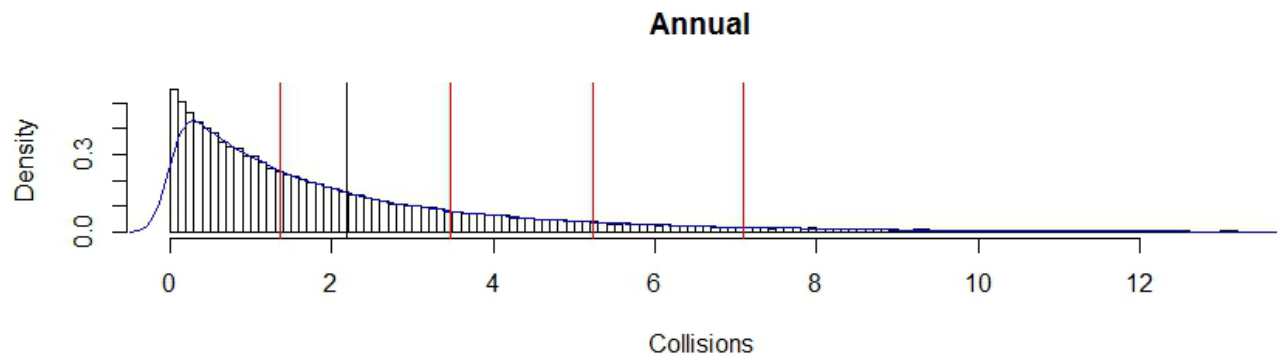
Inputs		Notes
Approximate Location (GPS)	Lat: 43.40261 Long: -111.73753	
# of Turbines	32	Maximum proposed
Rotor Swept Radius	0.050 km	50-meter radius
Count Duration	0.333 hours	20 minutes
Count Cylinder Vol	0.402 km ³	800-meter radius, 200-meter height
Daylight Hours	28,465 ^(a) hours	Adjustment to total turbine daylight hours
Eagle Minutes	0	No pre-construction surveys
Number of Counts	0	No pre-construction surveys
Collision Prob. Prior	Beta (2.48, 1023.55)	Collision Posterior C2 (see above)

a. Daylight hours represent the annual sum of the estimated number of daylight hours that each turbine was not spinning. This number is subtracted from the total annual daylight hours in the expansion factor calculation. See “Expansion Factor Calculation” in Section C.2 and the R-code in Attachment 2.

C.4 Running the Bayesian Model

As described in Appendix D of the ECPG, the Service’s Bayesian model calculates predicted fatalities using Gibbs sampling. As a result, the mathematical form of the posterior distribution is known because the distributions specified for the data and the prior are in the same family (known as conjugacy). To make inference on the parameters of interest (exposure and collision in this case), values are drawn from the mathematical representation of the posterior ($n = 100,000$ for Horse Butte) to obtain the posterior distribution. Distributions of predicted fatalities for each species at the Project are depicted in Figure 1, with golden eagles represented in the top graph and bald eagles in the bottom. The vertical black line in each graph depicts the mean annual fatality prediction. The red vertical lines represent the median (Q50) and 80th, 90th, and 95th quantiles (Q80, Q90, and Q95, respectively) (from left to right) for each annual prediction. The 80th quantile is the number the Service uses as a prediction of golden eagle collisions.

Golden Eagles



Bald Eagles

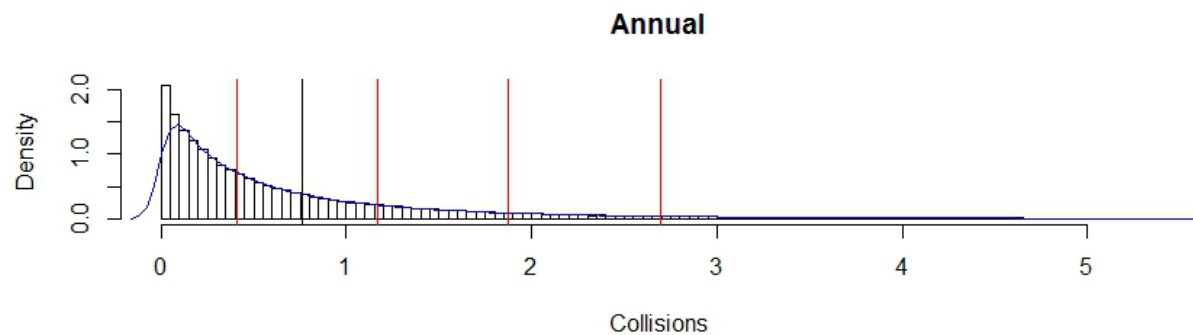


Figure 1: Annual Predicted Eagle Fatalities

Model results of take predictions for each species per year, including the mean standard deviation (SD), Q50, Q80, Q90, and Q95 are depicted in Table 4. Numbers in yellow are predictions at the 80th quantile, the quantile chosen to conservatively predict fatalities when issuing an eagle take permit.

Table 4: Summary of Model Outputs for Take Predictions in Eagles per Year.

	Golden Eagles						Bald Eagles					
	<i>Mean</i>	<i>SD</i>	<i>Q50</i>	<i>Q80</i>	<i>Q90</i>	<i>Q95</i>	<i>Mean</i>	<i>SD</i>	<i>Q50</i>	<i>Q80</i>	<i>Q90</i>	<i>Q95</i>
Prediction	2.2	2.5	1.4	3.5	5.2	7.0	0.8	1.0	0.4	1.2	1.9	2.7

C.5 Conclusion

Annual fatality predictions will be used to calculate the amount of eagle take to be authorized over the tenure of a five-year permit. The modelling described above predicts, at the 80th quantile, that 3.5 golden eagles and 1.2 bald eagles will be killed annually at the

Project. Over five years, that equates to 17.5 golden eagles and 6 bald eagles. If an eagle permit is issued for this project, the Service would round these numbers up to the nearest whole number and authorize the incidental take of 18 golden eagles and 6 bald eagles over the five-year permit term.

C.6 Literature Cited

Hull, C.L., and S. Muir. 2010. Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australian Journal of Environmental Management* 17: 77-87.

USFWS. 2013. Eagle Conservation Plan Guidance: Module 1—Land-based Wind Energy, Version 2. U.S. Fish and Wildlife Service Division of Migratory Bird Management. April.

Whitfield, D. P. 2009. Collision avoidance of golden eagles at wind farms under the 'Band' collision risk model. Report from Natural Research to Scottish Natural Heritage, Banchory, UK.

Attachment 1

Bias Trial Datafiles and Inputs for FCMR Estimates

Persistence Trial Data

State	Type	Duration	Transition	State	Type	Duration	Transition
fresh	Type1	7	NA	fresh	Type1	4	NA
fresh	Type1	7	NA	fresh	Type1	28	NA
fresh	Type1	2	NA	fresh	Type1	28	NA
fresh	Type1	7	NA	fresh	Type1	28	NA
fresh	Type1	7	NA	fresh	Type1	5	NA
fresh	Type1	7	NA	fresh	Type1	14	NA
fresh	Type1	7	NA	fresh	Type1	14	NA
fresh	Type1	6	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	14	NA
fresh	Type1	5	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	5	NA
fresh	Type1	6	NA	fresh	Type1	5	NA
fresh	Type1	7	NA	fresh	Type1	28	NA
fresh	Type1	14	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	14	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	21	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	4	NA	fresh	Type1	21	NA
fresh	Type1	4	NA	fresh	Type1	21	NA
fresh	Type1	21	NA	fresh	Type1	21	NA
fresh	Type1	28	NA	fresh	Type1	7	NA
fresh	Type1	28	NA	fresh	Type1	7	NA
fresh	Type1	28	NA	fresh	Type1	7	NA
fresh	Type1	28	NA	fresh	Type1	7	NA

State	Type	Duration	Transition	State	Type	Duration	Transition
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	21	NA	fresh	Type1	3	NA
fresh	Type1	28	NA	fresh	Type1	7	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	28	NA
fresh	Type1	28	NA	fresh	Type1	14	NA
fresh	Type1	7	NA	fresh	Type1	21	NA
fresh	Type1	3	NA	fresh	Type1	28	NA
fresh	Type1	3	NA	fresh	Type1	14	NA
fresh	Type1	4	NA	fresh	Type1	6	NA
fresh	Type1	7	NA	fresh	Type1	6	NA
fresh	Type1	28	NA	fresh	Type1	14	NA
fresh	Type1	7	NA	fresh	Type1	7	NA

Detection Trial (Searcher Efficiency) Data

State	Type	Nd	kd
fresh	Type1	79	74

FCMR Inputs – Year 1

(Carcass search file contains no fatalities of either species.)

FatalityCMR

Carcass search data file:

Persistence trial data file:

Detection trial data file:

Timing of visits for search data trial:

Timing of visits for persistence trial:

Use search data? (No for rare detections)

Number of bootstrap iterations:

Model for persistence probability:

Model for detection probability:

Model for entry probabilities:

Risk threshold for evidence of absence:

model name suffix

For extrapolation:

Number of turbines of each type:

turbine types:

Proportion of turbine area searched:

Generate simulated data

RESET

About FatalityCMR

GO

Models_with_search_data

Log-Like

Models_without_search_data

Log-Like

right-click mode

FCMR Inputs – Years 2-3

(Carcass search file contains two fatalities for GOEA, and no fatalities for BAEA, over two years of survey.)

FatalityCMR

Carcass search data file:

select file

Persistence trial data file:

select file

Detection trial data file:

select file

Timing of visits for search data trial:

Timing of visits for persistence trial:

1,2,3,4,5,6,7,14,21,28

Use search data? (No for rare detections)

No

Number of bootstrap iterations:

250

Model for persistence probability:

Phi()

Model for detection probability:

P()

Model for entry probabilities:

B(unif)

Risk threshold for evidence of absence:

0.05

model name suffix

HBW-Yr2and3

For extrapolation:

Number of turbines of each type:

32

turbine types:

Type1

Proportion of turbine area searched:

0.6995

Generate simulated data

RESET

About FatalityCMR

GO

M:/MBHP/Bird Groups/RAPTORS/Projects/Wind_Projects/Horse Butte/Fata

M:/MBHP/Bird Groups/RAPTORS/Projects/Wind_Projects/Horse Butte/Fata

M:/MBHP/Bird Groups/RAPTORS/Projects/Wind_Projects/Horse Butte/Fata

Models_with_search_data

Log-Like

Npar

Models_without_search_data

Log-Like

Npar

right-click model

Attachment 2

R-Code for Collision Probability Prior Updates

Daylight Hours Calculation

```
#####  
###      CALCULATING DAYLIGHT HOURS FOR A PROJECT      ###  
#####  
  
source('C:/Users/mstuber/Eagle_FatalityModel_Code/DayLen.R')  
  
### Approx Coordinates for Project  
LatLng<-c(43.402611, -111.737528)  
SeasonType<-"Annual"  
  
DayLtHr<-DayLen(LatLng[2],LatLng[1],Type=SeasonType,Labels=names(SeasonType))  
colnames(DayLtHr)[1]<-"Season"  
DayLtHr$AveDayLen<-with(DayLtHr,DayLtHr/Days)  
print(DayLtHr)
```

Update #1: Updating Collision Probability Prior to Determine Posterior C1 (for both species)

```
#####  
###      GETTING MEAN AND SD FOR NEW COLLISION PROB PRIOR      ###  
#####  
  
source("C:/Users/mstuber/Eagle_FatalityModel_Code/RVSmry.R")  
source("C:/Users/mstuber/Eagle_FatalityModel_Code/MEEsimFatal.R")  
  
require(rv)  
UCI<-c(0.5,0.8,0.9,0.95)  
nSim<-100000  
ModelDescription<-"Horse Butte Wind - Determining posterior distribution on collision prob."  
nTurbine<-c(32)  
HazRadKm<-c(50/1000)  
HazKM3<-c(0.2*pi*HazRadKm^2)  
CntHr<-c(20/60)  
ExpSvy<-data.frame(row.names=c("Annual"),  
EMin=c(0),  
nCnt=c(0),  
CntKM3=c(0.2*pi*0.8^2),  
DayLtHr<-c((4460.877*nTurbine)-28465))  
Dead<-c(0.1379)  
AddTot<-TRUE  
  
setnsims(nSim)  
getnsims()  
PlotFile<-NULL  
nSvy<-nrow(ExpSvy)  
cSvy<-rownames(ExpSvy)  
SmpHrKM3<-c(ExpSvy$nCnt*CntHr*ExpSvy$CntKM3)  
ExpFac<-c(ExpSvy$DayLtHr*HazKM3)  
postBH1<-simFatal(BMin=ExpSvy$EMin,Fatal = Dead,SmpHrKm=SmpHrKM3,  
ExpFac=ExpFac,aPriExp=0.9684375,bPriExp=0.5519703,aPriCPr=2.31,bPriCPr=396.69)  
postCPr<-attr(postBH1,"CPr")  
postCPr  
  
#####  
###      DETERMINING ALPHA AND BETA FOR NEW COLLISION PRIOR      ###  
#####
```

```

estBetaParams <- function(mu, var) {
  alpha <- ((1 - mu) / var - 1 / mu) * mu ^ 2
  beta <- alpha * (1 / mu - 1)
  return(params = list(alpha = alpha, beta = beta))
}
estBetaParams(0.003433629,0.002190921^2)

```

Update #2: Updating Collision Probability Posterior C1 To Determine Posterior C2 for GOEA

```

#####
###      GETTING MEAN AND SD FOR NEW COLLISION PROB PRIOR      ###
#####

source("C:/Users/mstuber/Eagle_FatalityModel_Code/RVSmry.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/MEEsimFatal.R")

require(rv)
UCI<-c(0.5,0.8,0.9,0.95)
nSim<-100000
ModelDescription<-"Horse Butte Wind - Determining posterior distribution on collision prob."
nTurbine<-c(32)
HazRadKm<-c(50/1000)
HazKM3<-c(0.2*pi*HazRadKm^2)
CntHr<-c(20/60)
ExpSvy<-data.frame(row.names=c("Annual"),
EMin=c(0),
nCnt=c(0),
CntKM3=c(0.2*pi*0.8^2),
DayLtHr<-c((4460.877*nTurbine)-28465))
Dead<-c(4.7148)
AddTot<-TRUE

setnsims(nSim)
getnsims()
PlotFile<-NULL
nSvy<-nrow(ExpSvy)
cSvy<-(rownames(ExpSvy))
SmpHrKM3<-c(ExpSvy$nCnt*CntHr*ExpSvy$CntKM3)
ExpFac<-c(ExpSvy$DayLtHr*HazKM3)
postBH1<-simFatal(BMin=ExpSvy$EMin,Fatal = Dead,SmpHrKm=SmpHrKM3,
ExpFac=ExpFac,aPriExp=0.9684375,bPriExp=0.5519703,aPriCPr=2.444,bPriCPr=709.419)
postCPr<-attr(postBH1,"CPr")
postCPr

#####
###      DETERMINING ALPHA AND BETA FOR NEW COLLISION PRIOR      ###
#####

estBetaParams <- function(mu, var) {
  alpha <- ((1 - mu) / var - 1 / mu) * mu ^ 2
  beta <- alpha * (1 / mu - 1)
  return(params = list(alpha = alpha, beta = beta))
}
estBetaParams(0.006965528,0.002590714^2)

```

Update #2: Updating Collision Probability Posterior C1 to Determine Posterior C2 for BAEA

```

#####
###      GETTING MEAN AND SD FOR NEW COLLISION PROB PRIOR      ###
#####

```

```

source("C:/Users/mstuber/Eagle_FatalityModel_Code/RVSmry.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/MEEsimFatal.R")

require(rv)
UCI<-c(0.5,0.8,0.9,0.95)
nSim<-100000
ModelDescription<-"Horse Butte Wind - Determining posterior distribution on collision prob."
nTurbine<-c(32)
HazRadKm<-c(50/1000)
HazKM3<-c(0.2*pi*HazRadKm^2)
CntHr<-c(20/60)
ExpSvy<-data.frame(row.names=c("Annual"),
EMin=c(0),
nCnt=c(0),
CntKM3=c(0.2*pi*0.8^2),
DayLtHr<-c((4460.877*nTurbine)-28465))
Dead<-c(0.04485)
AddTot<-TRUE

setnsims(nSim)
getnsims()
PlotFile<-NULL
nSvy<-nrow(ExpSvy)
cSvy<-(rownames(ExpSvy))
SmpHrKM3<-c(ExpSvy$nCnt*CntHr*ExpSvy$CntKM3)
ExpFac<-c(ExpSvy$DayLtHr*HazKM3)
postBH1<-simFatal(BMin=ExpSvy$EMin,Fatal = Dead,SmpHrKm=SmpHrKM3,
ExpFac=ExpFac,aPriExp=0.9684375,bPriExp=0.5519703,aPriCPr=2.444,bPriCPr=709.419)
postCPr<-attr(postBH1,"CPr")
postCPr

#####
###      DETERMINING ALPHA AND BETA FOR NEW COLLISION PRIOR      ###
#####

estBetaParams <- function(mu, var) {
  alpha <- ((1 - mu) / var - 1 / mu) * mu ^ 2
  beta <- alpha * (1 / mu - 1)
  return(params = list(alpha = alpha, beta = beta))
}
estBetaParams(0.002420010,0.001533167^2)

```


Attachment 3

R-Code for Final Bayesian Model Run

Code for Golden Eagle Prediction (using Collision Probability Posterior C2 for GOEA)

```
source("C:/Users/mstuber/Eagle_FatalityModel_Code/RVSmry.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/FatalFcns.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/MEEsimFatal.R")

require(rv)
UCI<-c(0.5,0.8,0.9,0.95)
nSim<-100000
ModelDescription<-"Horse Butte Wind - using new collison priors and conj. update from Years 2 & 3 PCM"
nTurbine<-c(32)
HazRadKm<-c(50/1000)
HazKM3<-sum(0.2*pi*HazRadKm^2)
CntHr<-c(20/60)
ExpSvy<-data.frame(row.names=c("Annual"),
EMin=c(0),
nCnt=c(0),
CntKM3=c(0.2*pi*0.8^2),
DayLtHr<-c((4460.877*nTurbine)-28465))
### Comment out if no collision prior update required
# Dead<-c(0)
AddTot<-TRUE

setnsims(nSim)
getnsims()
PlotFile<-NULL
nSvy<-nrow(ExpSvy)
cSvy<-(row.names(ExpSvy))
SmpHrKm3<-with(ExpSvy,nCnt*CntHr*CntKM3)
ExpFac<-c(DayLtHr*HazKM3)
tmp<-with(ExpSvy,mapply(simFatal,BMin=EMin,Fatal = -1,SmpHrKm=SmpHrKm3,
ExpFac=ExpFac,aPriExp=0.9684375,bPriExp=0.5519703,aPriCPr=7.1715,bPriCPr=1022.403,SIMPLIFY=FALSE))

Fatalities<-rvmnorm(nSvy)
Exp<-data.frame(Mean=rep(NA,nSvy),SD=NA,row.names=cSvy)
for(i in 1:nSvy){
  # i<-1
  Fatalities[i]<-tmp[[i]]
  Exp[i,]<-attr(tmp[[i]],"Exp")
}
rm(tmp)
names(Fatalities)<-cSvy

nSvy<-length(Fatalities)
if(is.null(nSvy))nSvy<-1
FatalStats<-RVSmry(cSvy,Fatalities,probs=UCI)
if(AddTot){
  FatalStats<-rbind(
    FatalStats,
    RVSmry("Total",sum(Fatalities),probs=UCI)
  )
}

## Look at the results
print(ModelDescription)
print(nTurbine)
```

```

print(HazRadKm)
print(CntHr)

print(ExpSvy)
#Exposure rate
print(Exp,digits=3)
#Annual Collision Fatalities
print(FatalStats,digits=3)
# Plots
nPlot<-nSvy+as.integer(AddTot)
nCol<-floor(sqrt(nPlot))
nRow<-ceiling(nPlot/nCol)
xlim<-range(rvrange(Fatalities))
if(!is.null(PlotFile))jpeg(PlotFile)
par(mfrow=c(nRow,nCol))
for(iPlot in 1:nSvy){
  # iPlot<-1
  plotFatal(Fatalities[iPlot],probs=UCI,
    # xlim=xlim,add=FALSE, # uncomment this line to put the graphs for all of the strata
    # on the same scale
    main=cSvy[iPlot])
}
if(AddTot)plotFatal(sum(Fatalities),main="Total")
if(!is.null(PlotFile))dev.off()

```

Code for Bald Eagle Prediction (using Collision Probability Posterior C2 for BAEA)

```

source("C:/Users/mstuber/Eagle_FatalityModel_Code/RVSmry.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/FatalFcns.R")
source("C:/Users/mstuber/Eagle_FatalityModel_Code/MEEsimFatal.R")

require(rv)
UCI<-c(0.5,0.8,0.9,0.95)
nSim<-100000
ModelDescription<-"Horse Butte Wind - using new collison priors and conj. update from Years 2 & 3 PCM"
nTurbine<-c(32)
HazRadKm<-c(50/1000)
HazKM3<-sum(0.2*pi*HazRadKm^2)
CntHr<-c(20/60)
ExpSvy<-data.frame(row.names=c("Annual"),
  EMin=c(0),
  nCnt=c(0),
  CntKM3=c(0.2*pi*0.8^2),
  DayLtHr<-c((4460.877*nTurbine)-28465))
### Comment out if no collision prior update required
# Dead<-c()
AddTot<-TRUE

setnsims(nSim)
getnsims()
PlotFile<-NULL
nSvy<-nrow(ExpSvy)
cSvy<-(rownames(ExpSvy))
SmpHrKM3<-with(ExpSvy,nCnt*CntHr*CntKM3)
ExpFac<-c(DayLtHr*HazKM3)
tmp<-with(ExpSvy,mapply(simFatal,BMin=EMin,Fatal = -1,SmpHrKm=SmpHrKM3,
  ExpFac=ExpFac,aPriExp=0.9684375,bPriExp=0.5519703,aPriCPr=2.483,bPriCPr=1023.554,SIMPLIFY=FALSE
))

```

```

Fatalities<-rvmnorm(nSvy)
Exp<-data.frame(Mean=rep(NA,nSvy),SD=NA,row.names=cSvy)
for(i in 1:nSvy){
  # i<-1
  Fatalities[i]<-tmp[[i]]
  Exp[i,]<-attr(tmp[[i]],"Exp")
}
rm(tmp)
names(Fatalities)<-cSvy

nSvy<-length(Fatalities)
if(is.null(nSvy))nSvy<-1
FatalStats<-RVSmry(cSvy,Fatalities,probs=UCI)
if(AddTot){
  FatalStats<-rbind(
    FatalStats,
    RVSmry("Total",sum(Fatalities),probs=UCI)
  )
}

## Look at the results
print(ModelDescription)
print(nTurbine)
print(HazRadKm)
print(CntHr)

print(ExpSvy)
#Exposure rate
print(Exp,digits=3)
#Annual Collision Fatalities
print(FatalStats,digits=3)
# Plots
nPlot<-nSvy+as.integer(AddTot)
nCol<-floor(sqrt(nPlot))
nRow<-ceiling(nPlot/nCol)
xlim<-range(rvrange(Fatalities))
if(!is.null(PlotFile))jpeg(PlotFile)
par(mfrow=c(nRow,nCol))
for(iPlot in 1:nSvy){
  # iPlot<-1
  plotFatal(Fatalities[iPlot],probs=UCI,
    # xlim=xlim,add=FALSE, # uncomment this line to put the graphs for all of the strata
    # on the same scale
    main=cSvy[iPlot])
}
if(AddTot)plotFatal(sum(Fatalities),main="Total")
if(!is.null(PlotFile))dev.off()

```