U.S. Fish and Wildlife Service Prior Analysis (Version 2)

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Process for Updating the Priors

In the Eagle Conservation Plan Guidance (ECPG) for incidental take of eagles associated with wind energy, the U.S. Fish and Wildlife Service (Service) developed a collision risk model (CRM) to predict the number of golden and bald eagles that may be killed at wind facilities (USFWS 2013; New et al. 2015). The CRM incorporates existing knowledge of eagle use around a proposed wind facility (exposure) and the probability of an eagle colliding with an operating turbine. This information is meant to reflect how exposure and collision probability can vary across the nation and takes the form of prior probability distributions. These distributions of *prior* knowledge are combined with project-specific information to predict the number of fatalities expected for a particular wind facility. The Service intends that these priors be updated (USFWS 2013) as new information becomes available. However, given the CRM's specific management context and the policy decisions reflected in assumptions, the Service must ensure that information used to update the priors is representative, transparent, and appropriate.

The ECPG defines a protocol for incorporating site-specific information into the CRM. Data collected to inform exposure and collision needs to be spatially and temporally representative of the project and its habitat. The CRM assumes a project's exposure data is collected before a wind facility's construction. This requirement eliminates the need for post-construction eagle use surveys, but it means the effects of any changes in eagle abundance and use of a site before and after construction are not directly estimated. Instead, they are accounted for indirectly in the model outputs. The survey data includes observations of eagle flight minutes and the amount of effort, in both space and time, put into the surveys. The site-specific updates to the collision probability requires data on eagle fatalities once a wind facility has become operational. Estimates of post-construction mortalities from carcass monitoring surveys should use relatively unbiased estimators, such as Huso (2009) or Péron et al. (2014). Estimators that bias fatalities towards zero (e.g., Smallwood 2007) should not be used. All fatality estimators also require trials to accurately estimate the probability that observers will detect carcasses (searcher efficiency) and that carcasses may be removed from the landscape (scavenging and/or persistence). If any of the information needed to inform exposure or collision probability is missing (e.g., in the case of exposure, if eagle use data are collected after a wind facility is constructed), the data are not appropriate for use in the CRM.

Following the ECPG, the Service can use the information described above to update the prior distributions for exposure and collision to project-specific estimates, called posterior distributions. These distributions represent eagles' use and risk at a particular wind facility.

These posteriors can also be combined with posteriors from other projects and used to update the national priors without any need to reanalyze the data in the CRM or through alternate approaches (e.g., Band et al. 2007). To update the national priors, data must be available from a sufficient number of sites to ensure representation across the nation, both in terms of pre-construction exposure and post-construction fatalities. The project-specific data must meet the criteria required for appropriate application of the CRM. Once enough new information becomes available, the Service can use mixture distributions to combine the respective project-specific posterior distributions for exposure and collision probability. This allows the new national priors to capture both intrinsic variability, as well as the spatial and temporal variability among projects across the nation. The Service has committed to conducting a formal notice and public comment process for any revision or update to the national priors before implementing them to estimate take rates for projects.

Beginning in 2016, the Service initiated a review of information in its files that could be used to update the national priors used in the CRM. That review confirmed that sufficient project-specific data were available to warrant such an update. This document reports on the results of that exercise, and provides the resulting proposed updates to the national CRM priors.

Wind Facility Data

Each Service Region was individually contacted and asked to provide all available records on wind facilities located in the states and territories under their purview. The Regions were specifically asked not to filter the records, but to provide all available information, no matter how small. As a result, the type of records received varied for each wind facility. In some cases, only letters, maps or names of wind facilities in summary documents or emails were available. Some wind facilities only had records of monitoring for bats, not avian species, while others had full documentation. Where possible, additional sources of information was also sought from online resources. To the authors' knowledge only wind facilities under direct Office of Law Enforcement (OLE) investigation were excluded, and this was at the indirect request of OLE. The records made available to the authors from the Regions came from 38 states (Alabama, Alaska, Arizona, Arkansas, California, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, Montana, Nevada, New Hampshire, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, Washington, West Virginia, Wisconsin, Wyoming) and one territory (Puerto Rico).

As of 31 December 2016, a total of 419 wind facility records from across the U.S. were provided to the authors by Service Regions 1-8. The data were collected in the field by over 20 environmental consultants, state and federal agencies, NGOs and other organizations, with not all providers tallied. The records from each facility were examined to determine whether there were data available that could be used to inform the national priors for collision probability and exposure. A defined set of criteria were used to determine the suitability of each wind facility. In addition, using these criteria, the specific reason each of the 419 wind facilities was included or excluded from the analysis of exposure and collision probability was recorded and the reasoning discussed with a representative of the appropriate Region to make sure that no pertinent information was overlooked.

For exposure, the criteria were as follows:

- The wind facility was terrestrial
- Raw data, or documented data summaries, were available to the Service
- The data were collected prior to the construction of the wind facility
- Eagle minutes, or eagle observations, were recorded and available to the Service
- Bald and golden eagle minutes or observations were uniquely specified
- The height and distance out to which eagles were recorded was documented
- The total amount of time spent sampling was documented, or could be inferred (e.g., 10 sampling locations, each surveyed three times for 30 minutes would give a total of 15 sampling hours)

Using these criteria, the Service identified 71 new wind facility sites that had data suitable for use in informing the prior distribution on exposure. When combined with the sites already used in the existing volumetric prior, information from a total of 80 wind facilities were available to inform the prior distribution on exposure. Of the 80 wind facilities, 40 were explicit that they monitored for both golden and bald eagles. The other half of the sites only made specific reference to one species of eagle, making it impossible to infer whether the unmentioned species was absent from the wind facility, or seen and not recorded. As a result, of the remaining wind facilities there were 21 that had data only relevant to golden eagles and 19 that had data only relevant to bald eagles. This gave a total of 61 wind facilities with information on golden eagle exposure and 59 wind facilities with information on bald eagle exposure.

When considering wind facilities for the collision probability prior, those that were not built, or are currently under construction, were immediately excluded. For an operating wind facility's data to be considered suitable to inform the collision probability prior, it had to first meet all of the criteria for the exposure prior. The additional criteria, specific to collision, were as follows:

- Data on eagle fatalities were collected post-construction
- Post-construction monitoring took the form of standardized surveys
- The details of the surveys, including the total duration of the monitoring, number of turbines searched, search interval, size of the search plots, and transect width were documented
- Estimates of both searcher efficiency and carcass persistence for the wind facility were documented, or could be inferred from raw data
- The number of operating turbines at the facility, as well as their height and radius, was documented
- All the required information and documentation were available to the Service

Using these criteria, the Service identified 18 new wind facility sites that had data suitable for use informing the prior distribution on collision. When combined with the sites already used in the existing collision prior, information from a total of 22 wind facilities were available to inform the prior distribution on collision probability. Of the 22 wind facilities, 14 had relevant data on both golden and bald eagles, while the remaining 8 had data relevant only to golden eagles. As a result, there were a total of 21 wind facilities with information on golden eagle collision probability and 13 wind facilities with information on bald eagle collision probability.

Prior Updates

The Service calculated project-specific posterior distributions of exposure and collision probability for all the wind facilities that met the criteria outlined above. For those sites where only eagle observations were collected, the analysis used a Poisson GLM to estimate eagle minutes and the resulting uncertainty was incorporated into the prior update. The resulting project-specific posterior distributions were combined using mixture distributions to calculate the mean and variance of the proposed new national priors for exposure and collision probability. Given the number of sites with appropriate information, separate exposure and collision probability priors were calculated for both golden (Fig. 1 and 4) and bald (Fig. 2 and 5) eagles.

The original exposure and collision probability priors for the Service's CRM were based solely on data from golden eagles. In addition to being based on a larger number of wind facilities, the priors presented here represent the first time the risk to bald and golden eagles have been considered separately, given the persistent belief that exposure and probability of collision for these two species is different. The data appear to support these conclusions, and may indicate that separate priors should be used for each species when evaluating a permit for a wind facility.

The very first exposure prior used by the Service used eagle minutes hr^{-1} km^{-2} as the unit of measurement (ECPG 2013). This was based on the assumption that all wind facilities would collect eagle exposure data from 0-200m above ground level (AGL). When calculating the hazardous space-time generated by operating wind turbines, a hazardous height of 0-200m AGL was also assumed. Both measurements were always conceived as volumetric, but height cancels out of the equation when both use 200m as the upper bound. Hence the original use of eagle minutes hr^{-1} km^{-2} as the units of measurement. As data from multiple wind facilities became available to the Service, it became apparent that not all data on eagle exposure were collected from 0-200m. As a result, the exposure prior was recalculated, using the same data, so that the units of measurement became eagle minutes hr^{-1} km^{-3} (New et al. 2015). Given the continued variation in the collection of eagle exposure data, and that fact that including height in the calculations when it the same for both exposure and hazardous space is equivalent to the eagle minutes hr^{-1} km^{-2} calculations, it is the volumetric prior that has been updated here.

The new exposure probability prior for golden eagles, Gamma(0.287, 0.237), has a mean of 1.21 eagle minutes hr^{-1} km^{-3} (SD: 2.25). For bald eagles, the exposure prior, Gamma(0.077, 0.024), has a mean of 3.19 eagle minutes hr^{-1} km^{-3} (SD: 11.46). This is in contrast to the original prior, Gamma(0.415, 0.0472), which had a mean of 8.79 eagle minutes hr^{-1} km^{-3} (SD: 13.64). When comparing the distributions (Fig. 3) it is possible to see that the estimated average exposure for both species has decreased, although the shift is less pronounced with bald eagles. Biologically, bald eagles attain much greater local densities than golden eagles where they are abundant, therefore the more variable distribution with a greater average for this species makes intuitive sense.

The new collision probability prior for golden eagles, Beta(1.29, 227.6), has a mean of 0.0056 birds per minute of exposure (SD: 0.0049). For bald eagles, Beta(1.61, 228.2), the collision probability prior has a mean of 0.0070 eagles per minute of exposure (SD: 0.0055). This is in contrast to the original prior, Beta(2.31, 396.69), which had a mean of 0.0058 birds per minute of exposure (SD: 0.0038). When comparing the distributions (Fig. 6) it is possible to see that the mode has shifted to the left, so that the most likely value for each species' collision probability has decreased. The mean probability of collision has decreased slightly for golden eagles.

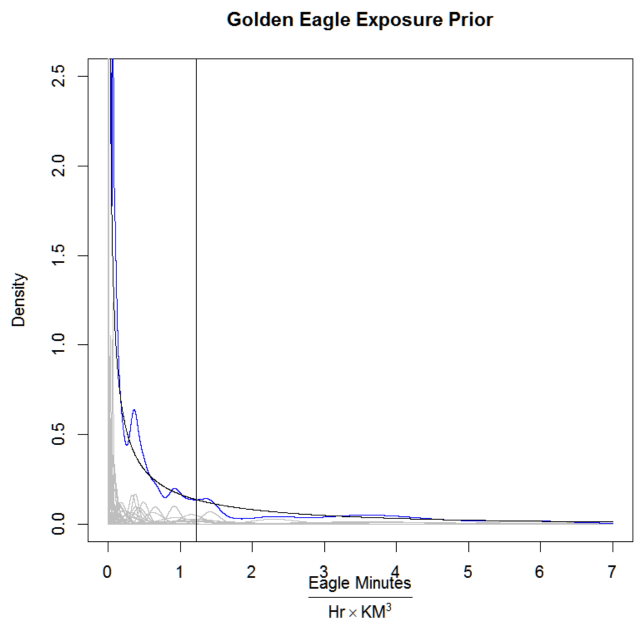

Fig. 1: New exposure prior for golden eagles (black). The distribution was based upon a mixture distribution (blue) built from the posterior distributions of collision probability from the 51 new sites with information on golden eagle exposure (grey). The black vertical line is the mean of the gamma distribution.

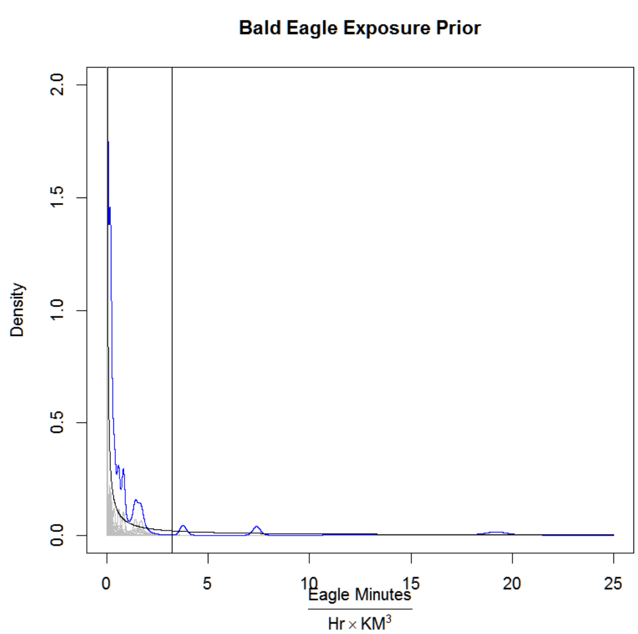

Fig. 2: New exposure prior for bald eagles (black). The distribution was based upon a mixture distribution (blue) built from the posterior distributions of collision probability from the 58 new sites with information on bald eagle exposure (grey). The black vertical line is the mean of the gamma distribution.

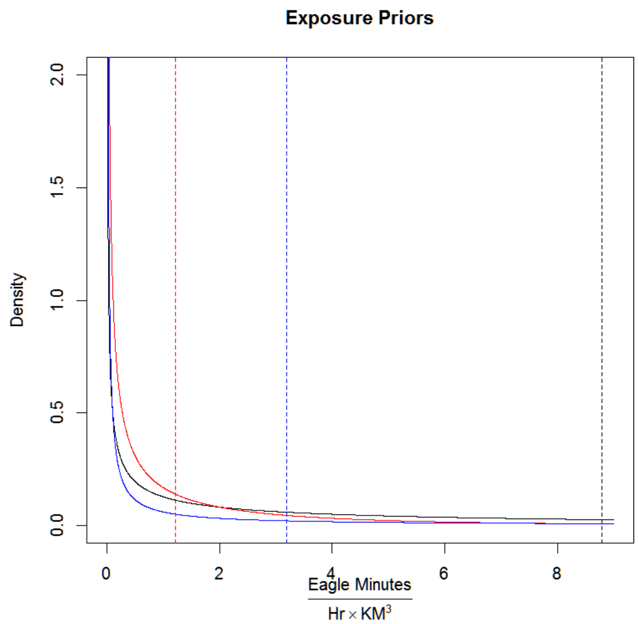

Fig. 3: The original (black) and new exposure priors for golden (red) and bald (blue) eagles. The dashed vertical lines represent the means of the respective distributions.

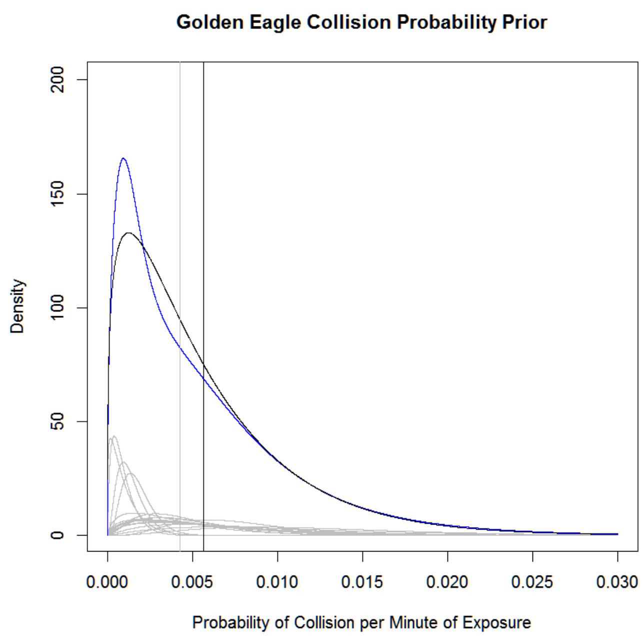

Fig. 4: New collision probability prior for golden eagles (black). The distribution was based upon a mixture distribution (blue) built from the posterior distributions of collision probability from the 16 new sites with information on golden eagle fatalities (grey). The black vertical line is the mean of the beta distribution, while the grey line is the 50th quantile.

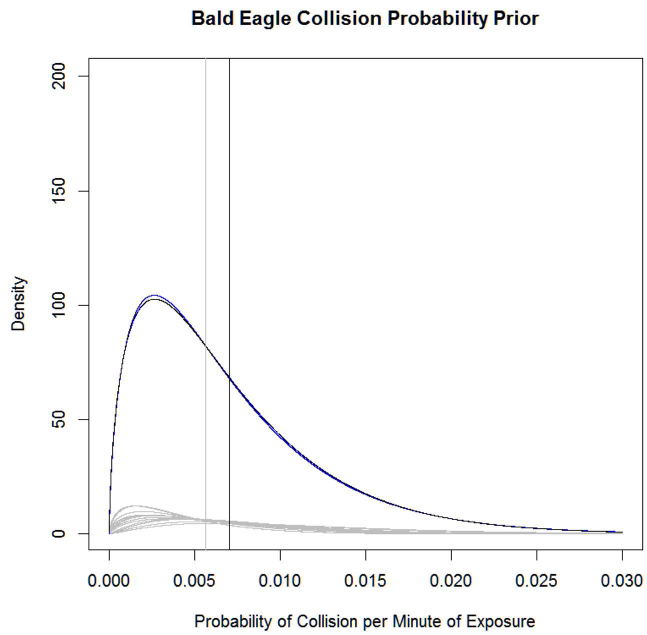

Fig. 5: New collision probability prior for bald eagles (black). The distribution was based upon a mixture distribution (blue) built from the posterior distributions of collision probability from the 12 new sites with information on bald eagle fatalities (grey). The black vertical line is the mean of the beta distribution, while the grey line is the 50th quantile.

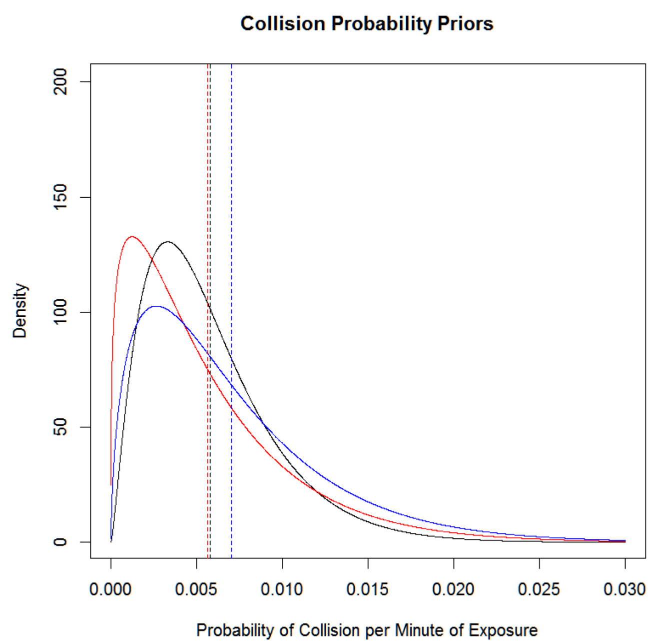

Fig. 6: The original (black) and new collision probability priors for golden (red) and bald (blue) eagles. The dashed vertical lines represent the means of the respective distributions.

However, our newly estimated mean probability for bald eagles is higher than the original, golden eagle-based, prior, which had previously been used for this species. This is because there is greater uncertainty in bald eagle collision probability when compared with the original collision probability prior, which will place more information in the tails of the distribution.

This may initially seem counter-intuitive, given that fewer bald eagles fatalities have been documented at wind facilities, when compared to golden eagles. However, biologically, this is not an implausible outcome. The range in abundance of bald eagles across the landscape is far greater than for golden eagles, and where bald eagles are abundant, they engage in social behaviors and intra-specific interactions that may make them more vulnerable than golden eagles to collisions. Thus, the implication that bald eagles are at high risk at a few wind facilities, while their risk is much lower at many others, is tenable.

Conclusions

It must be noted that although the priors have been updated, the Service's collision risk model has remained unchanged since first presented in the ECPG (2013). Changing priors does not change a model. Indeed, the basic method of sensitivity analysis when taking a Bayesian approach is to apply several different prior specifications to the same underlying model structure (Gelman et al. 2004).

Lastly, it is worth commenting on the implications of the changes to the prior distributions. For a wind facility at which no information was collected pre-construction, the estimate of fatalities would decrease significantly for both bald and golden eagles. Using the expansion factor calculated in New et al. (2015) the 80th quantile for the original priors would be 42.8 eagle fatalities per year, while the updated golden eagle specific priors would result in a fatality prediction of 2.9 golden eagles a year and the bald eagle specific priors would result in a fatality prediction of 4.2 bald eagle fatalities a year.

We can also explore the implications of the priors, given the availability of pre-construction data. Using the eagle exposure information outlined in New et al. (2015), the 80th quantile for the predictions of eagle fatalities at the wind facility would be as follows: 11.01 eagle fatalities per year for the original priors, 11.32 golden eagle fatalities per year for the golden eagle specific priors and 13.84 bald eagle fatalities per year for the bald eagle specific priors. The higher prediction of bald eagle fatalities is because there is almost no prior sensitivity in exposure, so the posterior distribution on that parameter is almost identical for each of the three prior specifications. As a result, it is the differences in the bald eagle collision probability prior that drive the higher prediction in this case.

Lastly, continuing with the data used in New et al. (2015), we look at the resulting predictions once post-construction data are available. The mean of the posterior distribution for fatalities is 4.81 eagles a year for the original priors, 4.47 eagles a year for the golden eagle specific priors, and 4.75 eagles a year for the bald eagle specific priors. For the 80th quantile, the respective values are 6.34 eagles per year, 5.98 golden eagles per year and 6.32 bald eagles per year. This demonstrates the desired lack of prior sensitivity and the importance of collecting robust post-construction data.

As demonstrated above, the updated prior distributions for the Service's CRM will result in higher predictions of bald eagle fatalities compared to golden eagle fatalities. This will help the Service better assess the positive take limits currently allowed in the eagle management units, given the uncertainty associated with bald eagle life history that leads to the potential for greater risk. However, upon the collection of robust post-construction data, the Service's CRM will accurately reflect what is occurring at the wind facility.

References

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