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The Bayesian Eagle - risk Model: Input Implications, Study Design, and Fatality Estimates

Photo by Doug Backlund

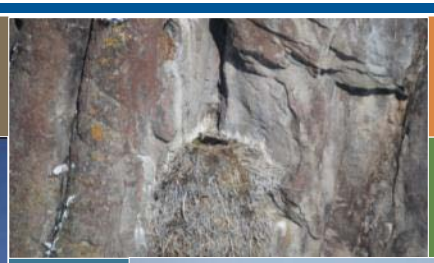

Photo by Russell Reynolds

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Fatality Risk Models

- Objective
  - Predict annual eagle fatalities
    - Needed for an Eagle Conservation Plan
- Role of fatality assessment
  - Acceptable under the no-net-loss standard
  - Determines amount of compensatory mitigation
  - Allows companies to manage risk and economics
- USFWS put forth 2 models to evaluate take
  - January 2011 - Draft Eagle Conservation Plan Guidance (initial/spreadsheet)
  - December 2011 - West Butte EA (Bayesian)
  - August 2012 – Technical Appendices (Bayesian)

Today's Objectives

- Overview of Bayesian model and its data inputs
- Explore behavior of Bayesian model
- Compare fatality estimates of Bayesian model to observed fatalities
- Overview of implications for pre-construction study design

Components of Eagle Fatality Prediction

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1. Measure

- Eagle minutes within the Project

2. Correct for

- Amount of time sampled
- Amount of project sampled
- Turbine avoidance
- Number of turbines

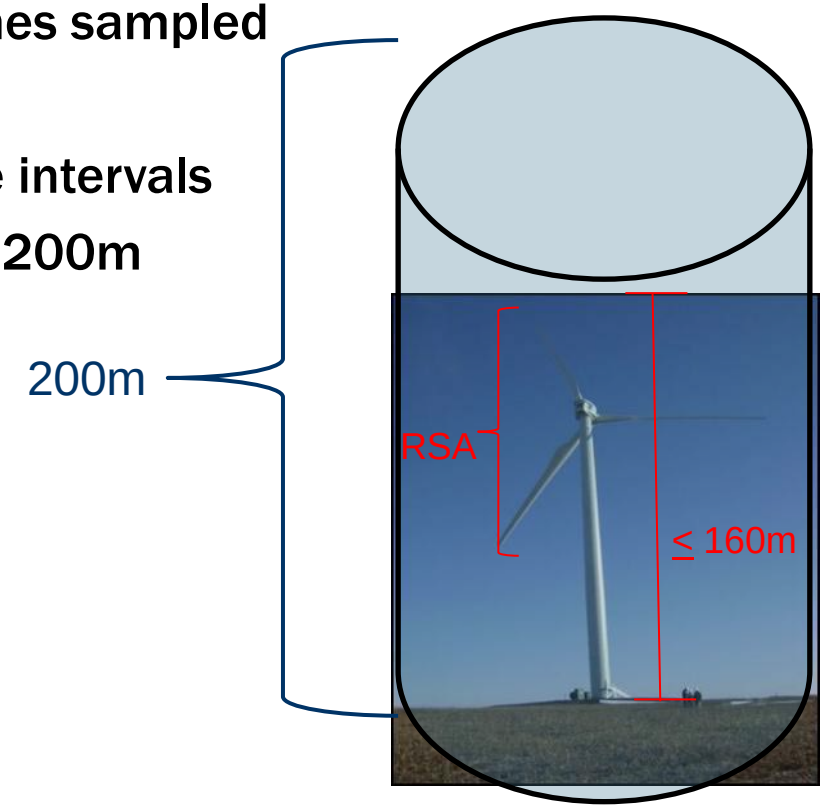
3. Mathematically translate into

- Estimate of eagle fatalities
- Estimate of variance

Photo by Tom Maechtle

Recommendations from Technical Appendices (2012)

- Point counts primary source for fatality estimation data
- Fixed, 800-meter radius
- 1-2 hours per point count
- ≥ 30% of 1-km buffer around turbines sampled
- All daylight hours sampled
- Record eagle positions at 1- minute intervals
- Record all heights as ≤ 200 m or > 200m
- ≥ 20 hours per turbine per year



Bayesian Statistics

- Starting point is based on a best guess at the data
- Draws information from distributions
- Has an adaptive management-like structure

Best guess at data (distribution) **Prior** → Collected data → Revised version of best guess at data (distribution) **Posterior** → Statistical answer

The Bayesian Fatality Model

$$F = \varepsilon \lambda C$$

Abbreviation	Variable	Description
F	Annual fatalities	Annual eagle fatalities from turbine collisions
λ	Exposure rate	Eagle-minutes flying within the project footprint (in proximity to turbine hazards) per hr per km^2
C	Collision probability	The probability of an eagle colliding with a turbine given exposure
ε	Expansion factor	Product of daylight hours and total hazardous area ($hr \cdot km^2$)

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Exposure Rate (λ)

- Prior drawn from a gamma distribution
  - Derived from Whitfield (2009) and projects under FWS review
- Posterior drawn from a gamma distribution defined by prior + observed exposure
  - i.e. posterior exposure is always > prior exposure

Collision Probability (C)

- Derived from Whitfield (2009) – golden eagles at 4 sites
  - Altamont, Foote Creek Rim, San Gorgonio, Tehachapi
- Drawn from a beta distribution

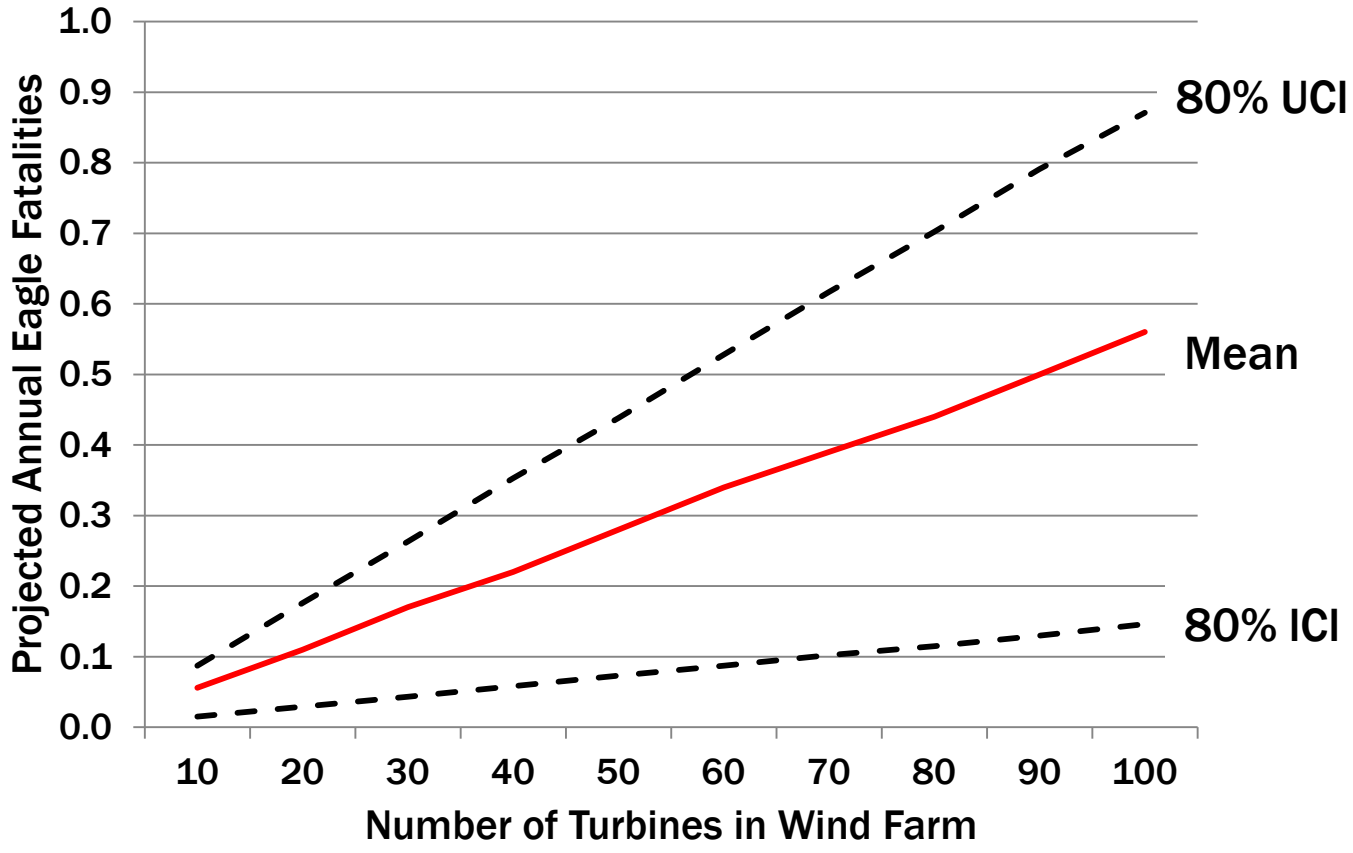
Expansion (ε)

A Function of -

- δ - circular hazardous area
- n_{turb} - number of turbines
- τ - total hours of daylight in the year (or other period of interest
- Turbine radius matters ($\delta = \pi r^2$) more than n_{turb}
- Thorough temporal sampling is rewarded (scaling up to τ)

Increasing Number of Turbines has a Linear Effect

55-m radius, 20 points, 20 eagle minutes, 1-hr counts, biweekly



80% UCI = 80% upper credible interval

Increasing Rotor Radius has a Nonlinear Effect

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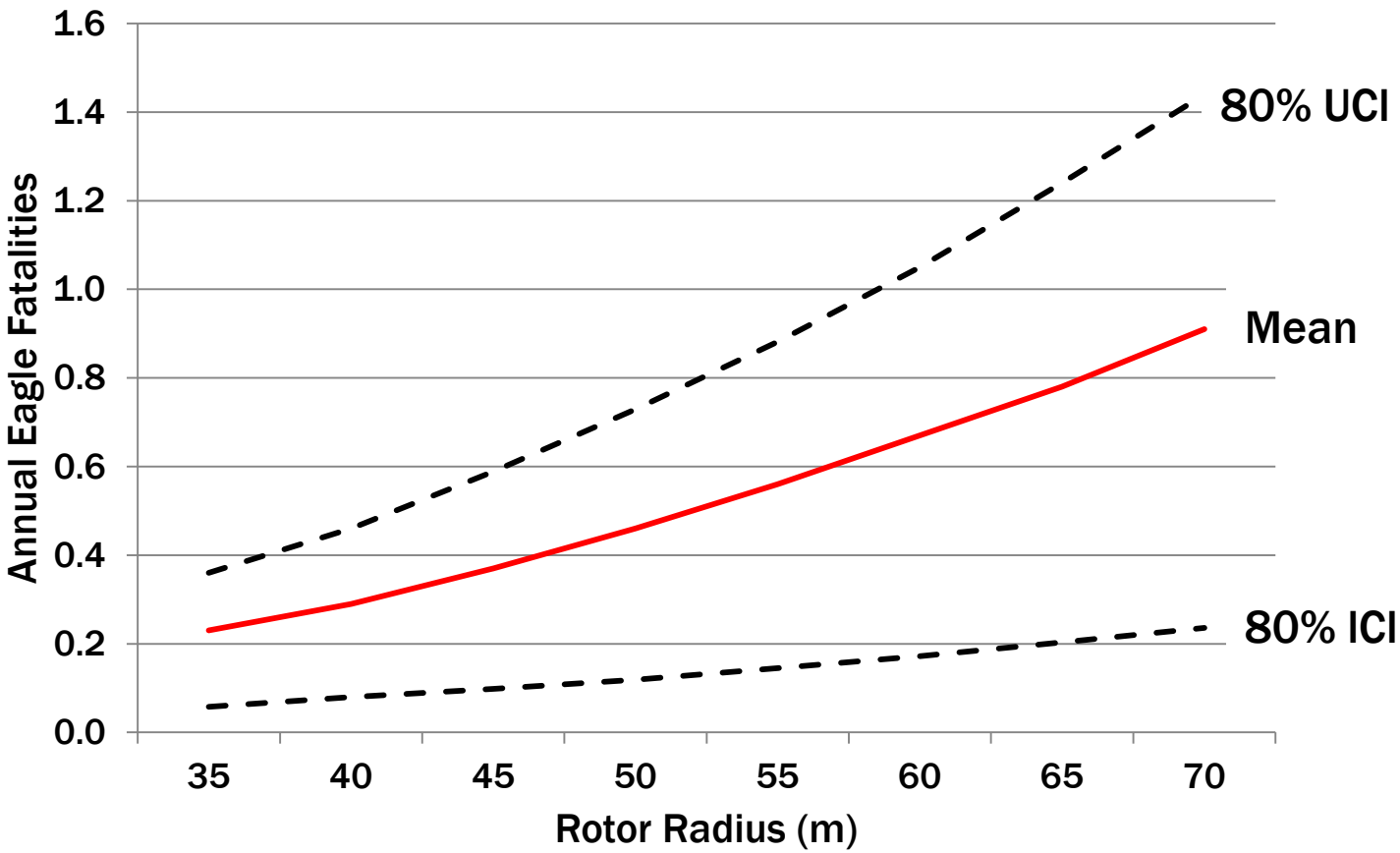
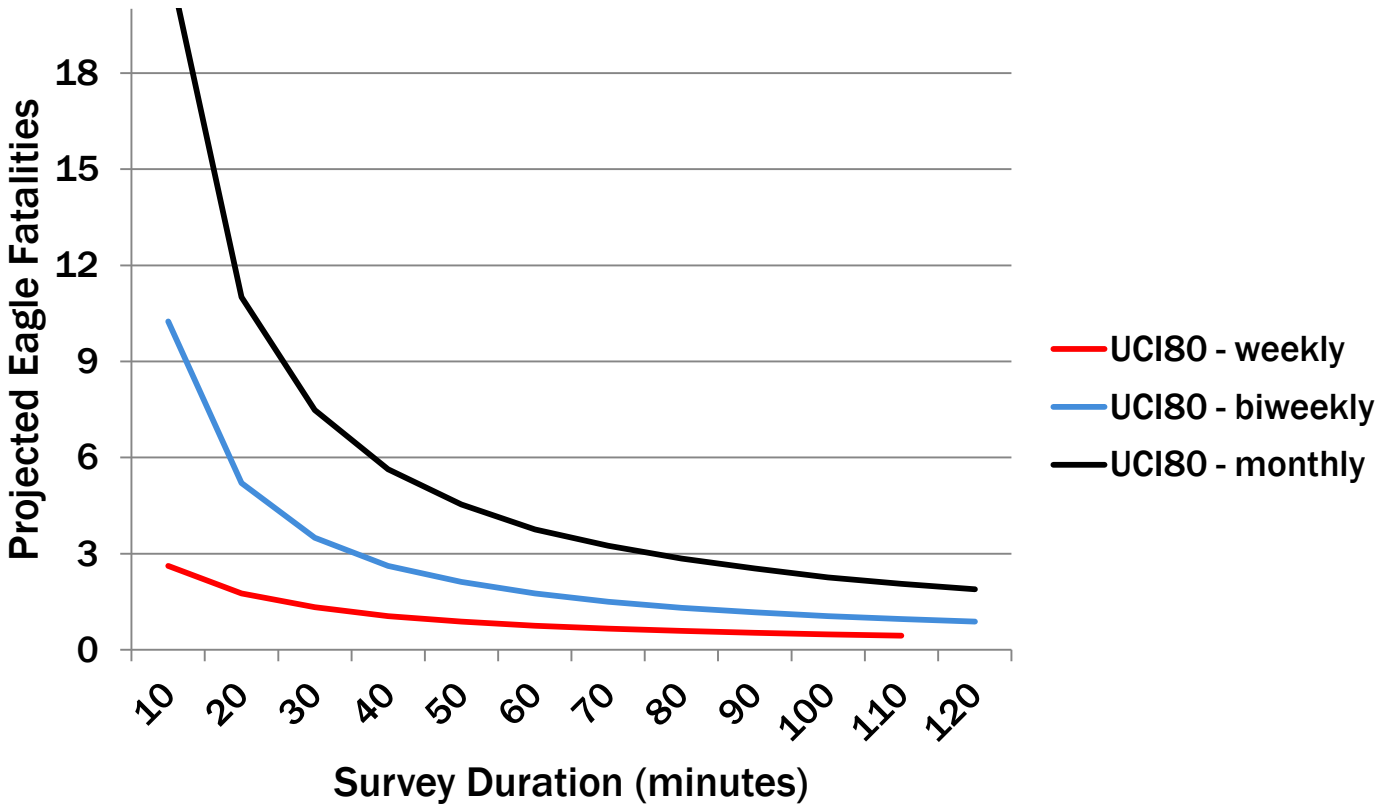
100 Turbines, 20 points, 1-hr counts, biweekly, 20 total eagle minutes



Increasing Survey Duration Decreases Estimate

100 Turbines, 55-m radius, 20 points, 20 total eagle minutes



Increasing Number of Counts Decreases Estimate

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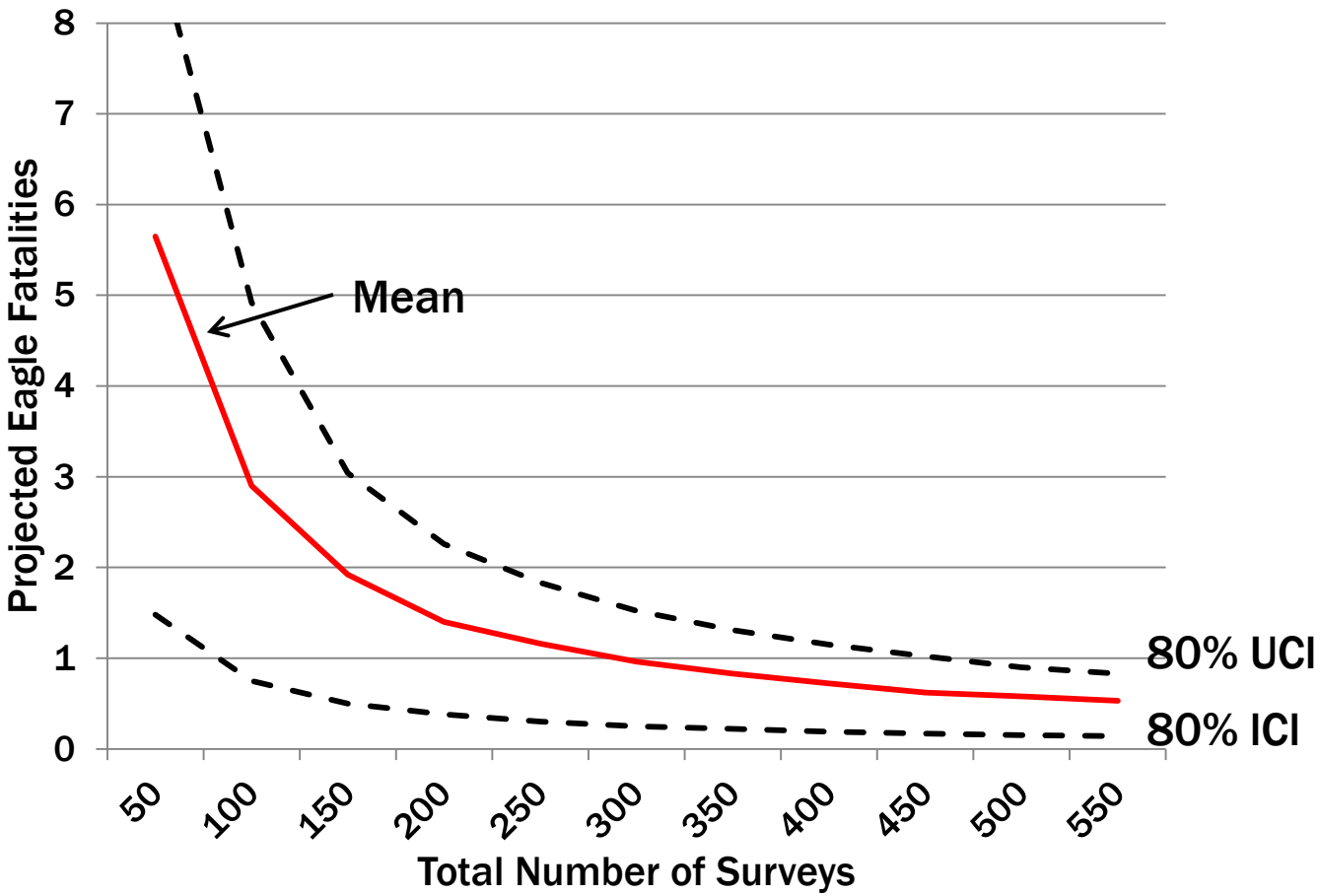
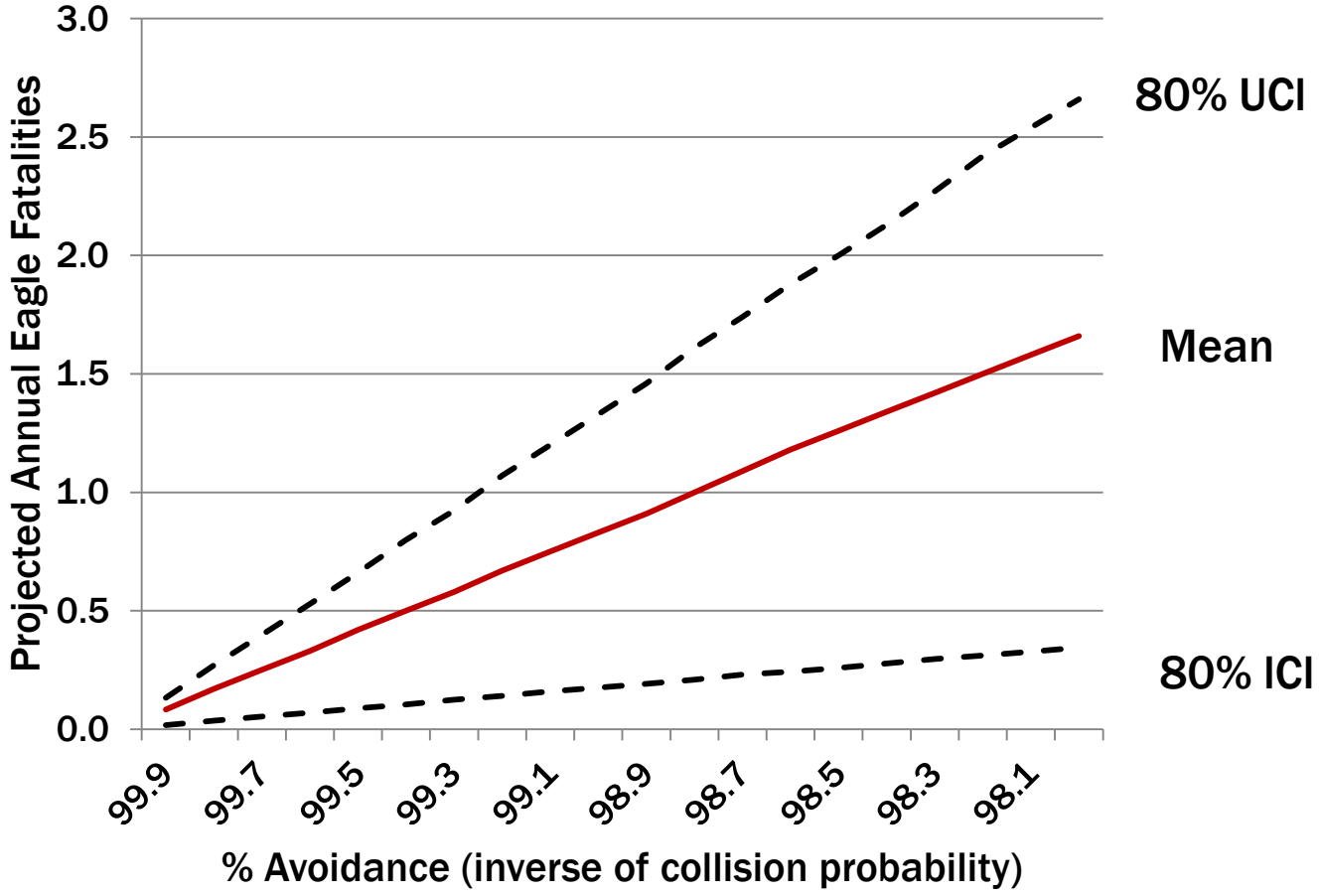
100 Turbines, 55-m radius, 20 points, 1-hr counts, biweekly, 20 total eagle minutes

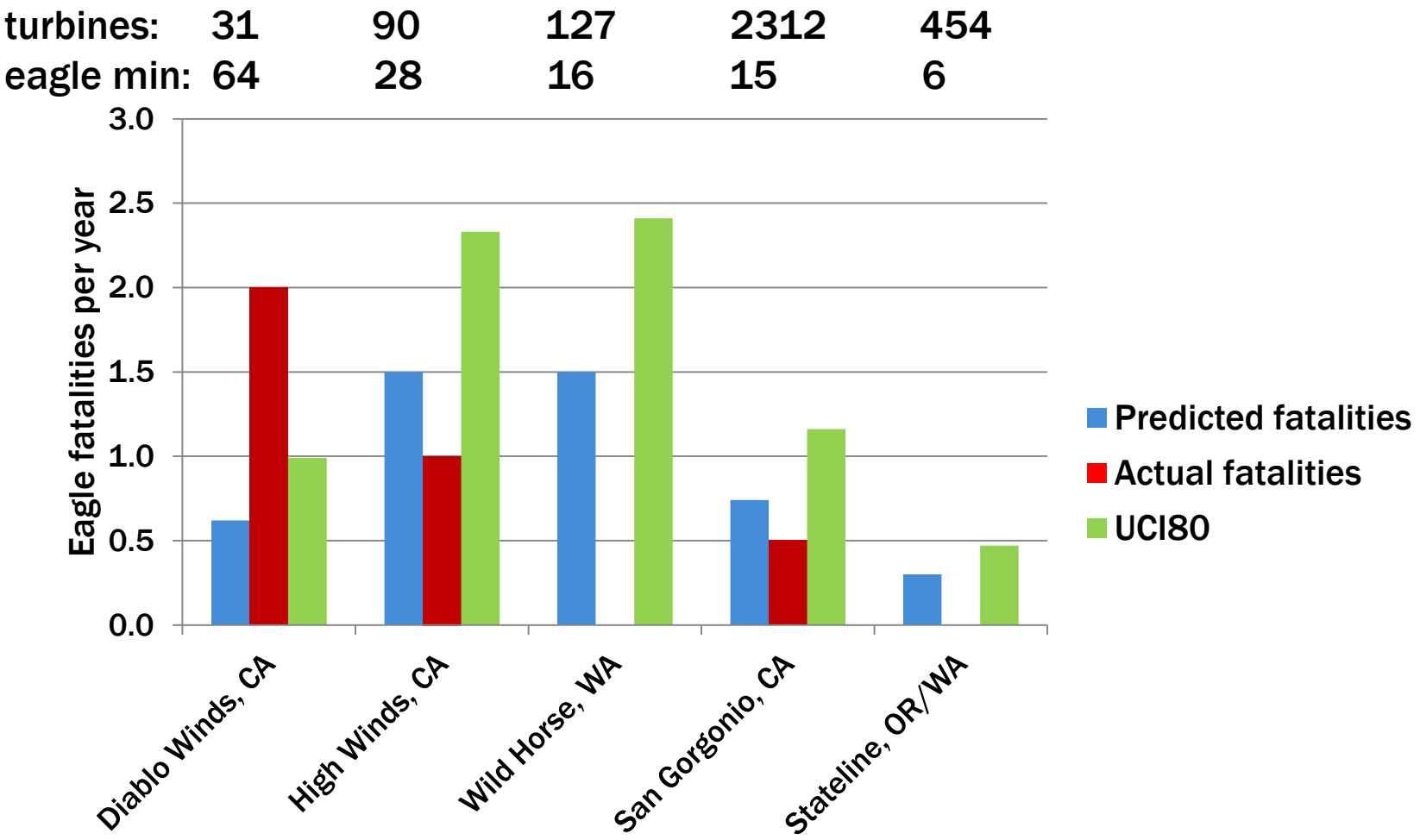


Collision Probability Strongly Affects Estimate

100 Turbines, 55-m radius, 20 points, biweekly, 20 total eagle minutes



How does the Bayesian Model Perform?



A Bald Eagle Example

Photo by Drake Schmidt

- 3 Turbines
- 2 years' data
- 30-minute counts
- 67 counts
- 231 eagles below 200 m
- No minutes recorded
- Assume 1 minute per eagle
- Model projects: 1.4 fatalities per year
- Model 80% UCI: 2.2 fatalities per year
- Observed Fatalities: 0

Photo by Russell Reynolds

Take Home

Bayesian model

- Allows you to keep “learning” from new data
- Isn’t easily accessible because of the level of statistics

What you should think about when planning surveys

- The tradeoff between turbine size and number of turbines is asymmetric
- More surveys translates to fewer projected fatalities
- Longer surveys translates to fewer projected fatalities (asymptotic)
- An inappropriate collision probability CAN hurt you
- Cause of collisions is not well understood – hard to model what you don’t understand