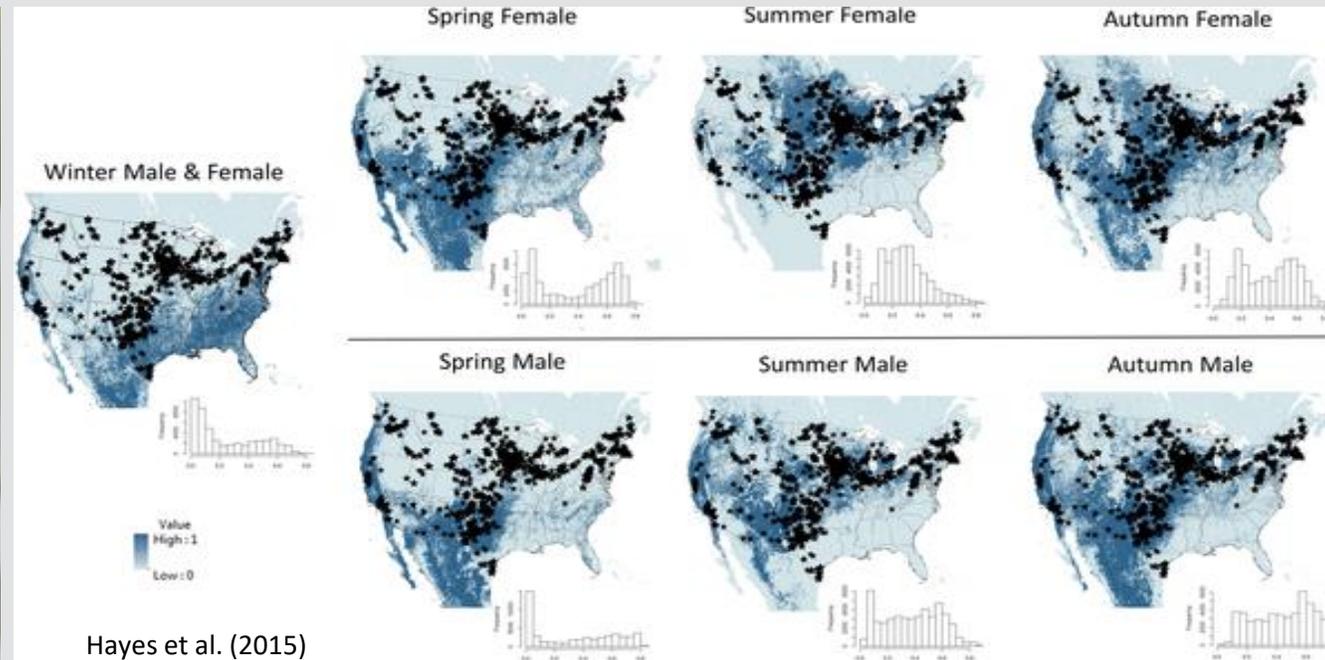
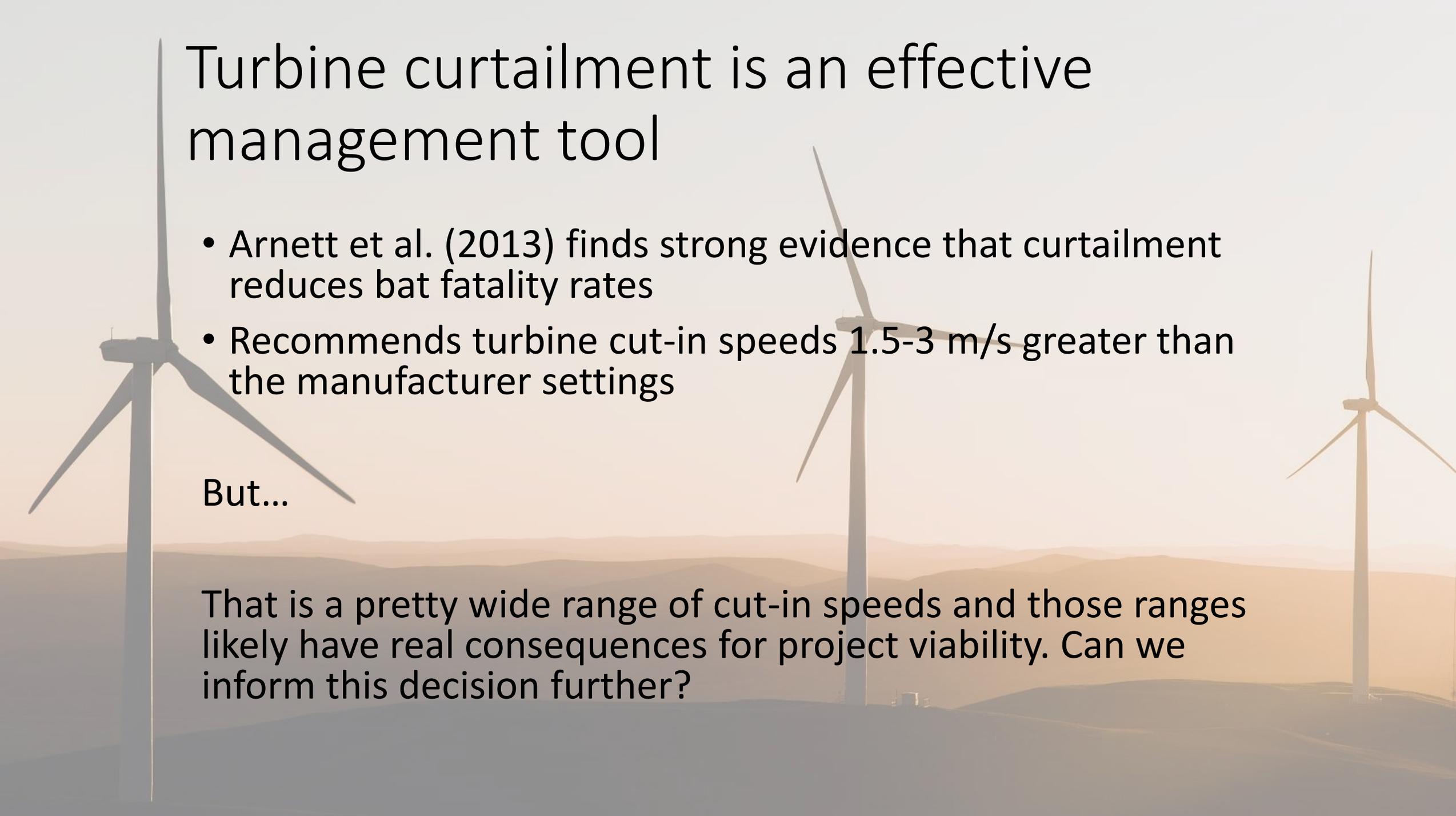


Assessing the effectiveness and measurement of curtailment strategies for reducing bat fatalities at terrestrial wind farms

Bat conservation and terrestrial wind

- Bat populations are difficult to study, have dynamic ranges, and many species are thought to be declining
- Collision rates for bat—particularly migratory tree bats—can be high at terrestrial wind turbines
- Turbine fatality rates may be high enough to impact hoary bat population status (Frick et al. 2017)





Turbine curtailment is an effective management tool

- Arnett et al. (2013) finds strong evidence that curtailment reduces bat fatality rates
- Recommends turbine cut-in speeds 1.5-3 m/s greater than the manufacturer settings

But...

That is a pretty wide range of cut-in speeds and those ranges likely have real consequences for project viability. Can we inform this decision further?

Study Questions

Ecological

- What is the effect of turbine curtailment on bat fatality rates?
- Do larger magnitude curtailments (Δ m/s) lead to fewer fatalities?

Methodological

- How much information do we need to successfully evaluate these questions?
- How effective are individual turbine fatality studies in measuring fatality reductions?

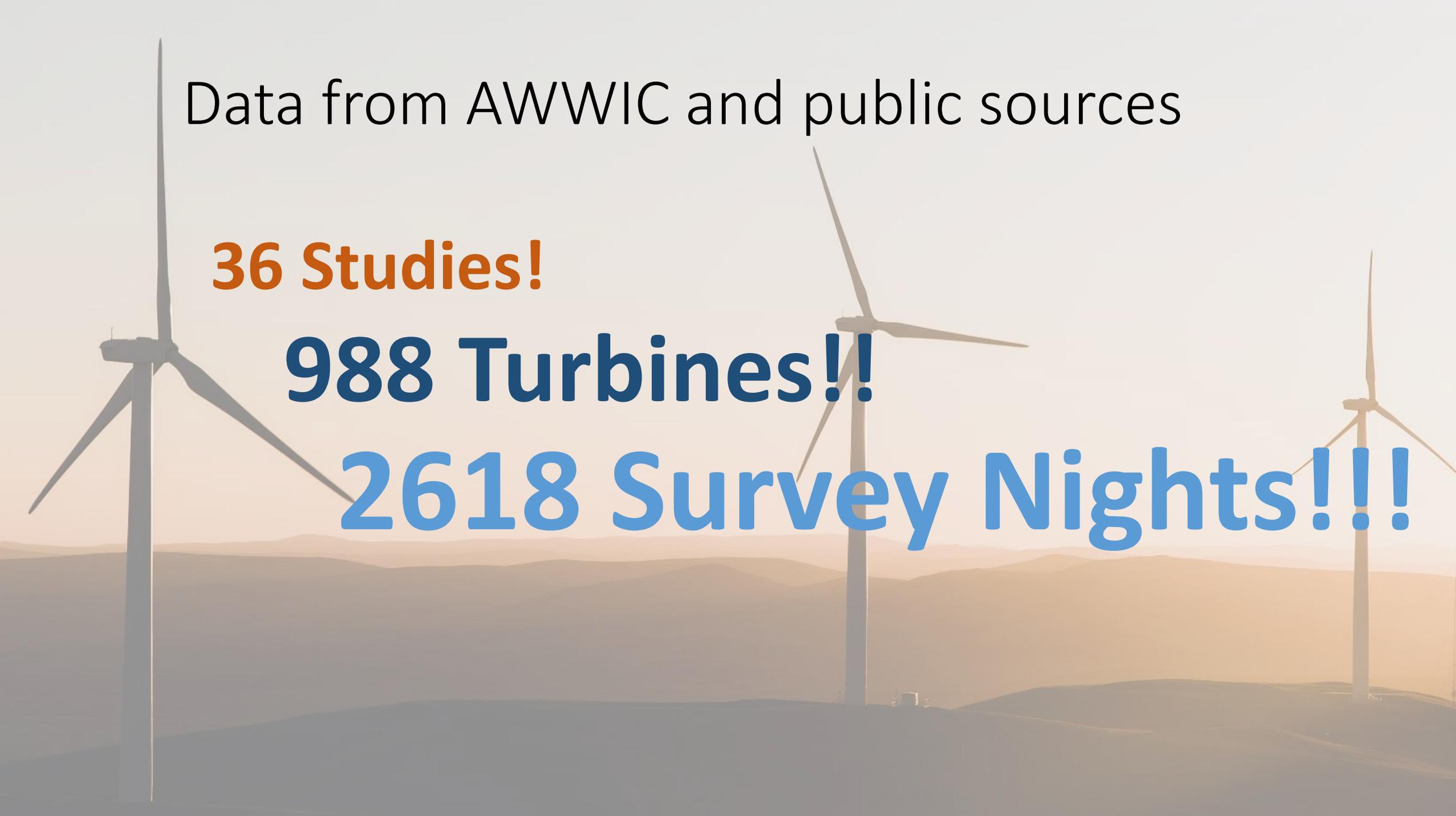
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The background of the slide features a hazy, golden-hour landscape with several wind turbines. The turbines are silhouetted against a warm, orange-toned sky. The foreground shows rolling hills and the lower parts of the turbine towers. The overall atmosphere is serene and emphasizes renewable energy.

Data from AWWIC and public sources

36 Studies!

988 Turbines!!

2618 Survey Nights!!!

Study

Effect Size (\pm Uncertainty)

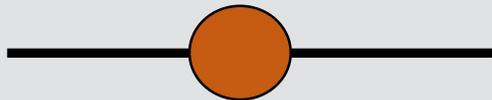
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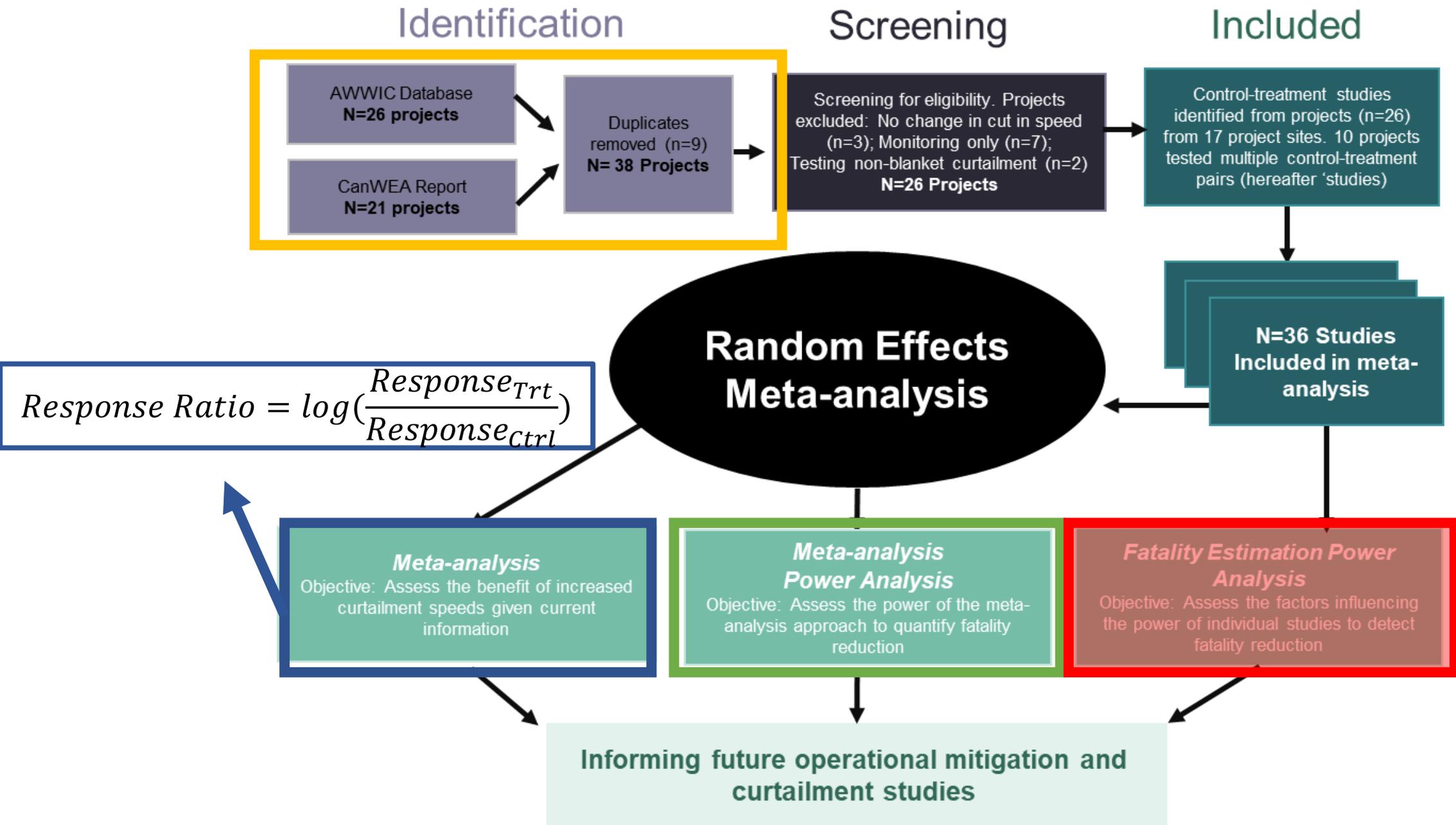
Sum



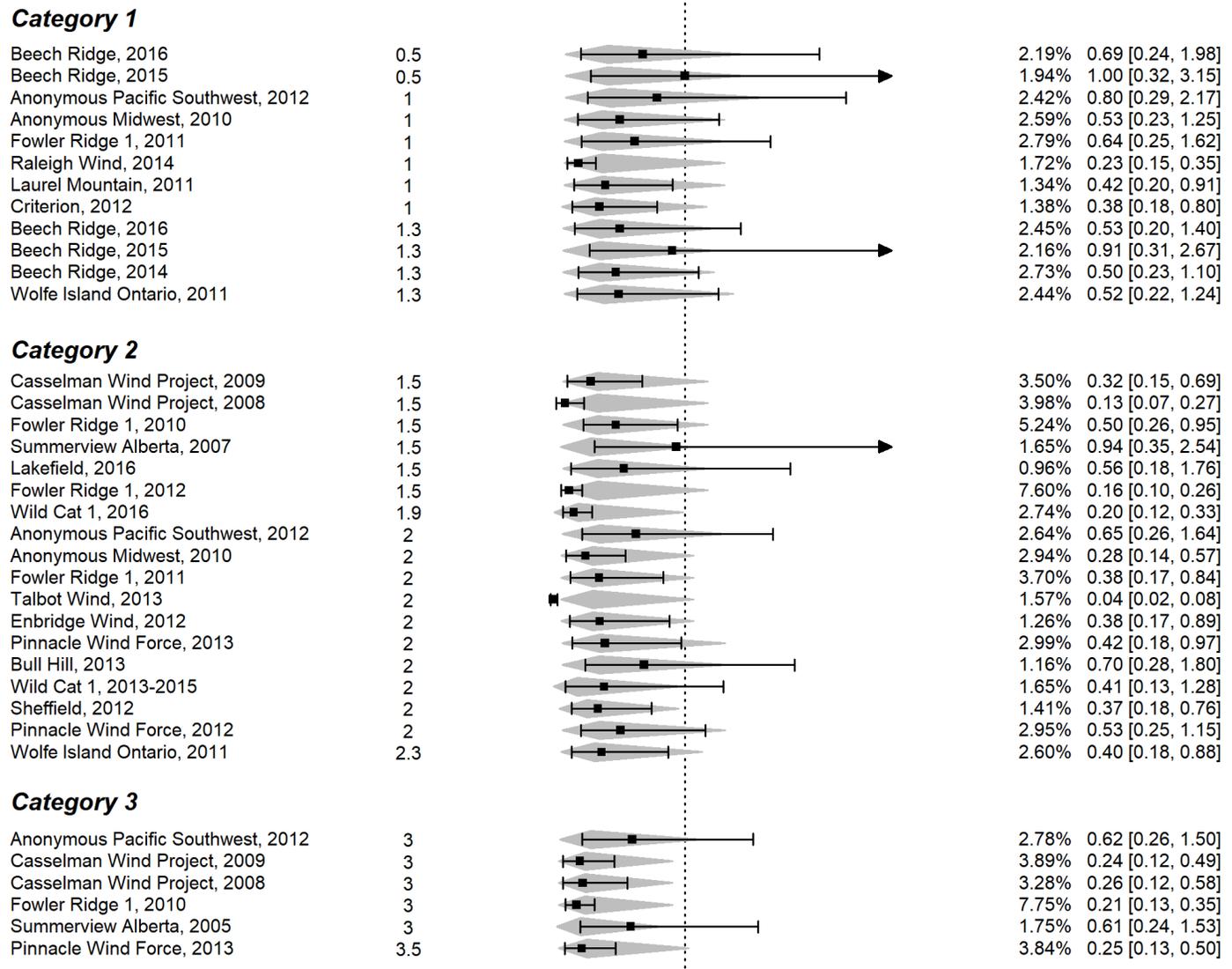
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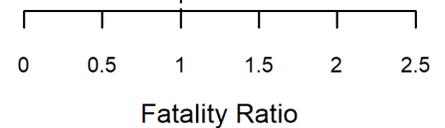
$\mu_{\text{meta}} \pm SE$



Study, Year Δ Cut-in Weight Fatal. Ratio



Overall Effect 0.37 [0.30, 0.46]



Results: Overall meta-analysis

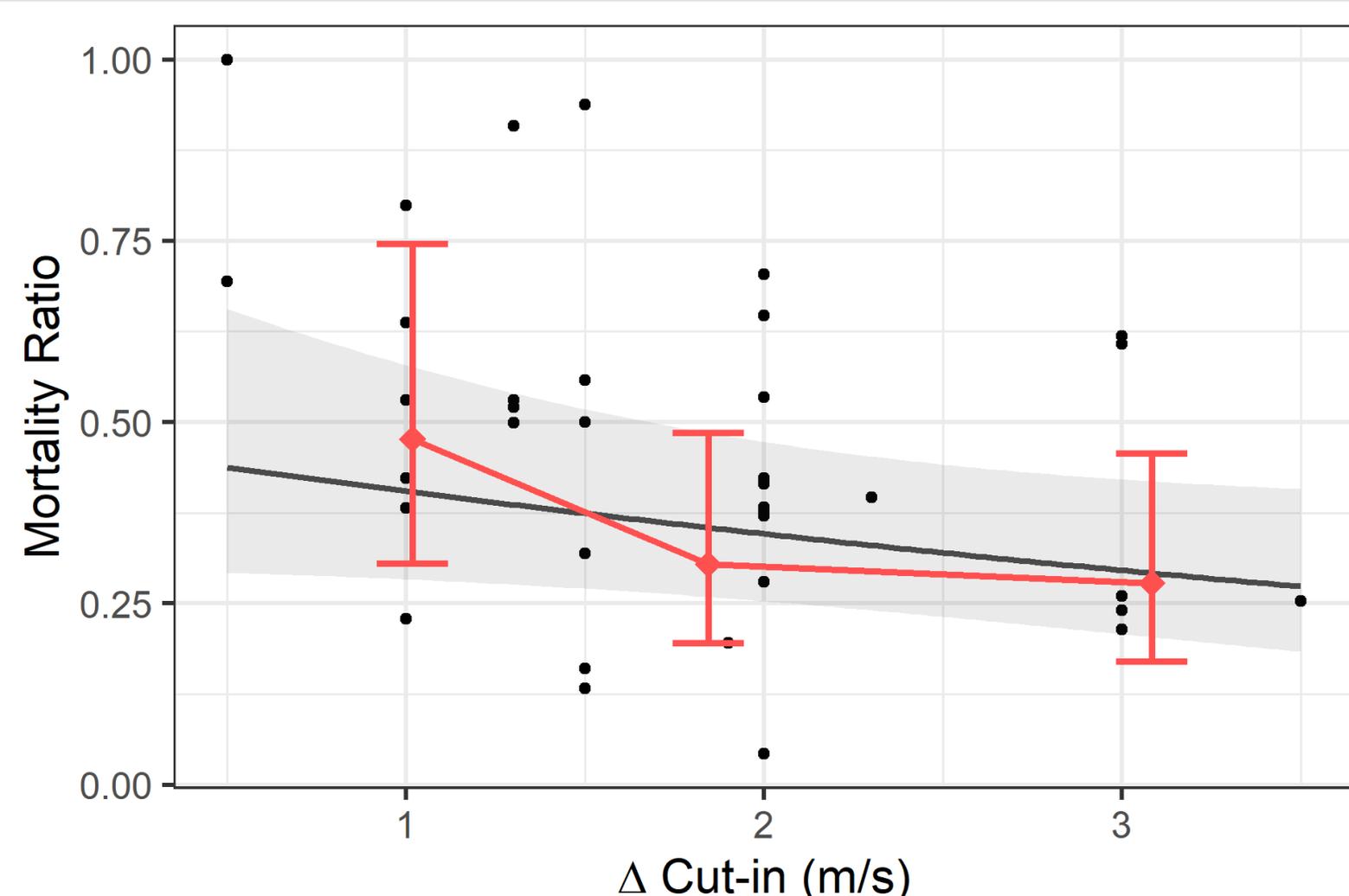
Curtailment decreased fatalities in these studies by **63% [95% CI: 55-70%]**

Fatality reduction ranged from **0 – 96%** across all studies

Results: Increasing Curtailment Speed

Increasing curtailment speeds reduced fatality rates but the shape of the relationship is uncertain

- Linear Model
 - Fatality decrease of 14%/1 Δ m/s ($p = 0.08$)
- Categorical Model
 - 17% decrease in fatality rates between $\sim 1 \Delta$ m/s and $\sim 2 \Delta$ m/s studies ($p=0.06$)
 - **20% decrease** in fatality rates between $\sim 1 \Delta$ m/s and $\sim 3 \Delta$ m/s studies ($p = 0.04$)
- Site was important
 - No evidence that control cut-in, region, or turbine dimensions mattered



A photograph of a bat hanging upside down from a tree branch. The bat's wings are partially spread, and its body is covered in brown and grey fur. The background is a soft-focus green forest. A dark grey rectangular box is overlaid on the image, containing white text.

So, how good are we at measuring these effects anyway?

Study Questions

Ecological

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Meta-analysis design analysis using a simulation approach

4 *a priori* scenarios in curtailment efficacy tested:

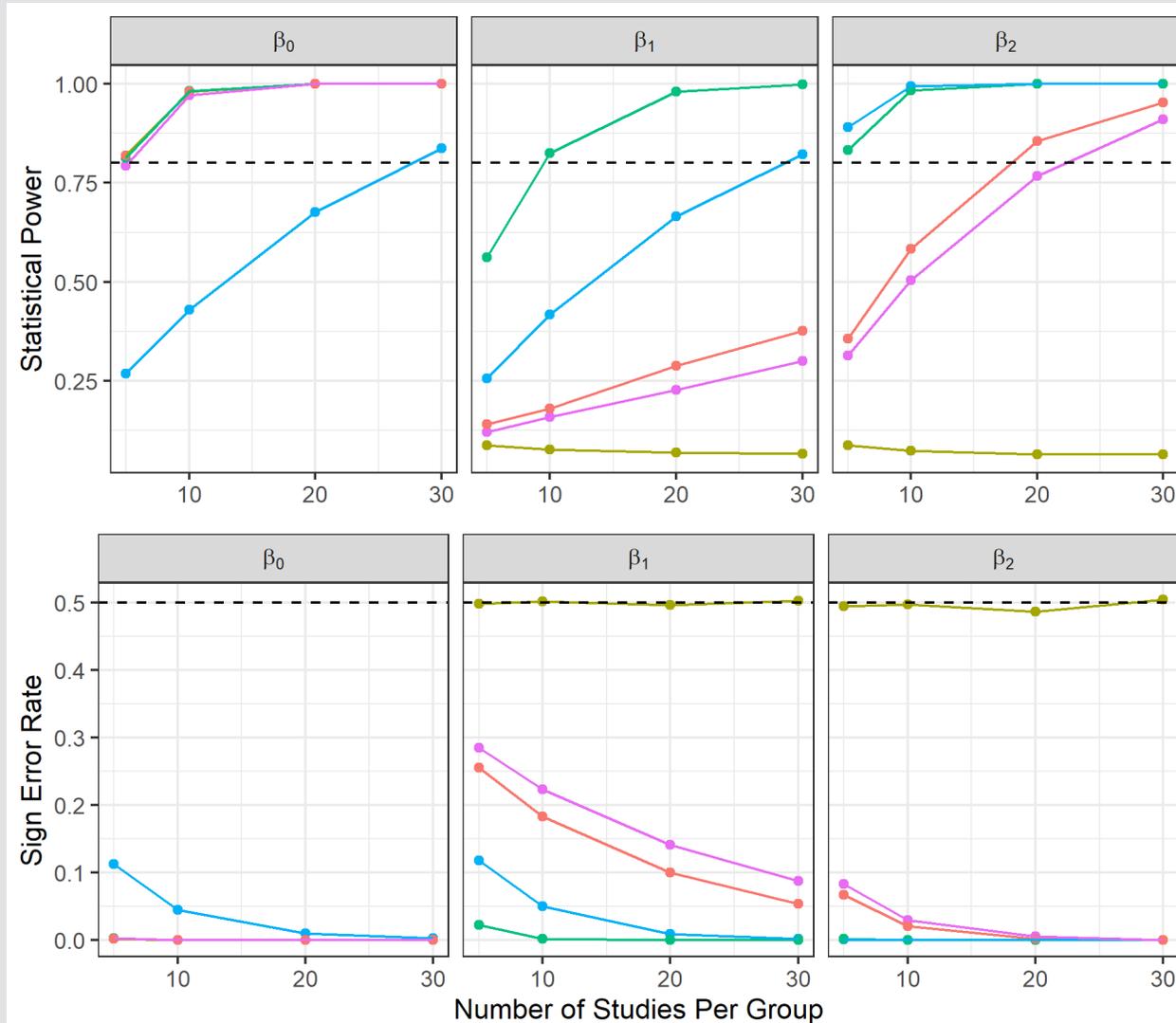
1. 25% linear decrease in fatality/ 1Δ m/s
2. 50% exponential decrease in fatality/ 1Δ m/s
3. 50% decrease in fatality with 1Δ m/s curtailment but no additional decrease
4. 50% initial decrease in fatality with 10%/ 1Δ m/s after

AND

5. an *a posteriori* scenario tested to determine adequate sample sizes based on this study's results

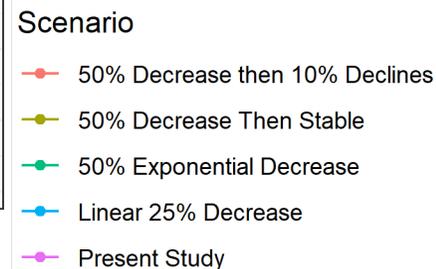
Results: Meta-analysis Study Design Analysis

Best at detecting fatality decreases of greater than 25%/1 $\Delta m/s$



5 studies per group were needed to achieve sufficient statistical power to measure the overall effect

20 + studies per group were needed for the 50% then stable scenario and the current knowledge scenario



Conclusions

- Curtailment is very effective overall, but variance across studies is high and we don't know all the factors driving those differences
- The magnitude of cut-in speed difference between control and treatment groups explained some of these differences, but high leverage studies create further uncertainty
- The meta-analysis can detect larger effects of changing cut-in speeds, but not smaller, so we have uncertainty to the shape of this relationship
- Overall, many studies have been conducted that are good at finding large effects with few studies that can detect smaller effects
- There was no evidence that turbine dimensions or ecoregion affect fatality rate reductions, though power is likely low for those variables
- Reducing the uncertainty in the effects of curtailment by improving experimental design would be helpful in maximizing our knowledge

Questions?

Thanks to:
Ryan Butryn
Juan Botero
All the AWWIC data contributors

