

Use of Pre-construction Acoustic Bat Data to Design and Forecast Site-specific Curtailment Plans

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Introduction

While a definitive quantitative link between acoustic bat activity levels and mortality rates at operating wind farms has yet to be established, acoustic bat data collected at turbine height provide detailed information on bat activity patterns and conditions under which bats are active. Assuming a link between activity levels of bats and risk of collision, wind developers can use pre-construction acoustic bat data collected from the rotor zone to evaluate potential cost and effectiveness of customized curtailment plans. Such early-stage curtailment forecasting would enable developers to predict realistic costs for multiple curtailment scenarios and propose specific curtailment strategies to regulatory agencies. This proactive approach can reduce uncertainty about the cost of curtailment and also reduce the chance that a regulatory agency would require more restrictive generic curtailment later in a project's life cycle.

Goals of Pre-construction Curtailment Forecasting

- Develop scientifically defensible curtailment scenarios early in a proposed wind project life cycle
- Balance needs and requirements of project developers, resource agencies, and project stakeholders
- Make best use of available pre-construction acoustic bat and meteorological data
- Predict realistic cost and potential effectiveness of various curtailment scenarios
- Avoid need for agency-mandated curtailment programs, which likely be generic and less flexible
- Design curtailment system around documented bat activity patterns on a site-specific basis

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Developer Needs/Goals

- Maximized operational revenue (operational time)
- Reduced risk of impacts to rare species
- Compliance with applicable environmental laws and regulations
- Compliance with applicable corporate avian/bat protection plans
- Accurate estimate of cost of curtailment
- Flexibility
- Focused curtailment to minimize down time
- Quantitative data to demonstrate effectiveness of curtailment

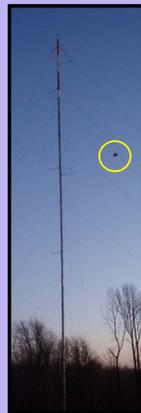
Proactive Curtailment Programs

- Can be designed pre-construction
- Avoid revenue loss due to unexpected down time
- Can be incorporated into corporate or site-specific avian/bat protection plans or conservation measures
- Can be tailored to characteristics of individual sites and designed based on preconstruction data
- Can be drafted and evaluated by developer with or without third party or regulatory agency involvement
- Can be flexible to account for uncertainty regarding anticipated bat mortality rates
- Can avoid the need for costly reactive curtailment measures

Site-specific Curtailment Forecasting

To generate a straightforward, site-specific model for curtailment using pre-construction data, the weather conditions during which bat activity occurred are compared to the overall distribution of weather conditions during the survey period. Bats' tendency to be active in the rotor zone during certain conditions can then be evaluated with a contingency table analysis. The developer can use the results of this analysis to design a curtailment plan combining temperature and wind speed data that curtails turbines during conditions when certain thresholds of activity occurred. This approach uses site-specific data to design and evaluate candidate curtailment plans according to the anticipated level of risk to bats and/or anticipated goals or requirements to reduce impacts by certain levels. Curtailment forecasting can therefore be based on simple to complex parameters to meet the needs of the developer at multiple or individual sites. This approach results in a plan that:

- Is developer-driven
- Is based on existing site-specific pre-construction data
- Relies on quantitative data and analysis
- Allows for accurate models of potential cost of curtailment
- Evaluates multiple scenarios early in project development
- Can be conducted on a season-specific level
- Can be conducted on a species-specific level
- Can incorporate multiple variables (time past sunset, wind speed, temperature, relative humidity, precipitation, barometric pressure, and the interaction between these variables)



Pre-construction Data

- Acoustic bat data from within rotor zone for entire season where bats may be active
- Co-located wind speed and temperature data collected at 10-minute intervals spanning bat survey period

Pre-construction surveys often include passive acoustic bat surveys. If detectors are deployed as high as possible in a meteorological tower, they are able to sample bat activity in the rotor zone of wind turbines and acoustic bat activity patterns can then be analyzed according to patterns of wind speed and temperature to better understand under what conditions bats are active. These data are relatively inexpensive to collect and can provide substantial quantitative data on which to base site-specific models for curtailment.

Regulatory Agency Needs/Goals

- Adherence to mandate to protect resources and species they manage
- Avoidance of impacts to rare species
- Technically defensible data on levels of impacts and impact reduction
- Consistency in recommendations and application of standards
- Curtailment measures that have been shown to be effective

In the absence of a proactive program, wind projects may be forced to develop more costly and less flexible reactive curtailment programs during operation.

Reactive Curtailment Programs

- Must be developed quickly and often result in lost revenue from mandatory shut-downs
- Are generally mandated by agencies and/or third parties and are likely generic, "off-the-shelf" plans
- Likely require involvement of agencies and other third parties
- Prioritize agency needs/requirements over developer's preferences
- Likely more restrictive as they are designed in response to a problem or known issue



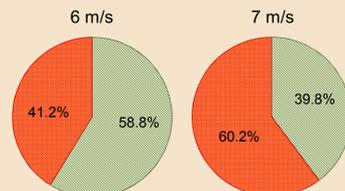
Case Study

Summary

- Acoustic bat activity monitored at 45m above ground from October 2008 to October 2009 in two separate towers at a proposed site in Texas
- Temperature and wind speed collected from the same locations at 45m
- Temperature and wind speed determined for each of 14,400 recorded bat call sequences
- Bats were most active at higher temperatures and lower wind speeds
- Contingency table analysis and a chi-square test indicated significant preference for conditions relative to available wind and temperature conditions (χ^2 statistic 2569, $df = 247$, $p < 0.001$)

Generic Curtailment Models

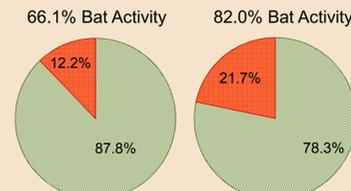
- 6 m/s curtailment would shut down turbines for 41.2% of time between 8 pm and 6 am, during conditions when 66.1% of bat activity occurred
- 7 m/s curtailment would shut down turbines for 60.2% of time between 8 pm and 6 am, during conditions when 82.0% of bat activity occurred



Percent of time between 8 pm and 6 am where turbines would be **curtailed** (red) and **uncurtailed** (green) under generic 6 m/s and 7 m/s curtailment to avoid conditions where 66.1% (left) and 82.0% (right) of acoustic activity occurred

Wind/Temperature Model

- Turbines would be curtailed during combinations of temperature and wind speed where a given threshold percentage of bat activity occurred
- Cut-in wind speeds vary by temperature according to the acoustic activity patterns documented on site
- Turbines could be curtailed for only 12.2% and 21.7% of the time between 8 pm and 6 am to avoid conditions during which the same percentages of acoustic activity occurred as 6 m/s and 7 m/s generic curtailment models, respectively

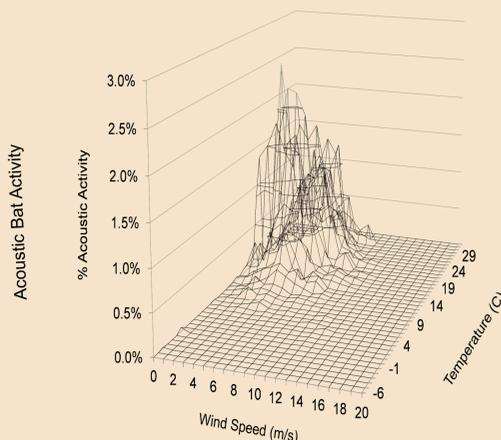


Percent of time between 8 pm and 6 am where turbines would be **curtailed** (red) and **uncurtailed** (green) under an activity-based wind/temperature curtailment model to avoid conditions where 66.1% (left) and 82.0% (right) of acoustic activity occurred

Conclusions

By incorporating both temperature and wind speed, curtailment programs can target conditions when bat activity levels are highest based on quantitative data collected at an individual site. This ensures that turbines are curtailed when bat activity and presumably risk are highest and allows turbines to rotate when conditions are not favorable for bat activity. Based on this case study, a basic wind/temperature curtailment model based on acoustic data could avoid the same amount of bat activity and thus reduce the potential for bat mortality as much as generic models with only one third or less turbine downtime. A more complex model incorporating additional variables could focus curtailment even further, resulting in even less downtime.

Site-specific curtailment models could be evaluated using multiple target thresholds for the percent of bat activity that is "avoided" allowing developers to predict the cost and likely effectiveness of multiple scenarios early in project development.



Distribution of acoustic bat activity versus wind speed and temperature

