NRG White Paper

Validation Methodologies for NRG Systems' Bat Deterrent System

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Overview

NRG Systems' Bat Deterrent System is designed to be installed on wind turbines and operated such that bat mortality at wind projects is reduced. Naturally, there is a desire among potential end-users to know what this reduction will look like at their facility. But measuring the efficacy of a Bat Deterrent System is highly nuanced. There are many variables – most of which are difficult to predict – that contribute to the perceived success or failure of a system. A robust validation study design, carried out prior to Bat Deterrent System installation, can yield statistically reliable results that provide a preview of what success could look like at a wind site. This paper will cover some of the study designs that NRG Systems is aware of, including the benefits and drawbacks of each method. Ultimately, any robust study design will yield a significant amount of data. NRG highly recommends the consultation of a biologist that is well-versed in study design and post-processing of the results. This will reduce the risk of going through the expense and time commitment of a trial that yields no significant statistical results.

Variables that can affect the success of a trial

Mix of bat species	**Time of year**	**Power of the study design**	**Location of study**	**Weather**	**Duration of study**
Searcher efficiency	**Carcass persistence (if mortality study)**	**Camera resolution (if using thermal cameras)**	**Wind turbine rotor diameter**	**Topography of wind farm**	**Number of wind turbines**

Power of a Study Design

Arguably the most important aspect of a validation study is understanding the statistical "power" of the study, which refers to how likely the study is to distinguish an actual effect from one of chance. The higher the power of a study, the more likely the results are valid. A study with low statistical power may have inconclusive results or leave doubt that there was any conclusion at all. Conducting a power analysis of a study will help understand the statistical significance of the study. The power analysis is important as it will allow the designer of the study to control some of the variables that can affect the success of a trial, such as the number of turbines used, the duration of the study, and how often a plot around a turbine is searched for bat carcasses. Running a power analysis may also help the designer evaluate whether the budget is sufficient to achieve the desired trial results.

Elements that yield a high power study include maximizing the number of test vs. control turbines, optimizing the data and data collection, and accommodating the longest study duration possible.

Study Design Options

NRG is aware of three methods to measure the efficacy of its Bat Deterrent System:

1. Mortality Study: A group of control turbines and test turbines run at the same time. Biologists search the area under each turbine for bat carcasses and catalog the results.
2. Video / Thermal Analysis: Long-range night vision or thermal cameras are used to monitor bats around the rotor-swept zone.
3. Acoustic Monitoring: Acoustic monitoring devices are used to capture whether bats are present in the affected air space.

Mortality Study

The most common form of efficacy testing for bat deterrents is the mortality study. The mortality study mimics the post-construction mortality (PCM) survey that most wind farms are required to perform following commissioning. One option is to modify the PCM by adding a bat mortality trial component. For a mortality study, a control group of wind turbines is required. This control group should be operating at whatever the standard parameters are for that wind farm. Perhaps the wind farm is already using mitigation methods such as feather-to-cut-in, which involves stopping turbine blades from spinning while they are not operational. In this case, the control group should also use feather-to-cut-in. The test group of turbines would have the Bat Deterrent Units installed and should operate under the parameters the study intends to prove. In this example, they should also run feather-to-cut-in, but they could also add other parameters such as curtailment if the site aims to prove the efficacy of a Bat Deterrent System when paired with curtailment.

One disadvantage of a mortality study is that there is little insight into the characteristics of the bat population present at the site. Since the assessment is made only from carcasses, we do not know with any certainty how many bats were near the turbines, or what the species make-up was during the study. One way to mitigate some of these unknowns is to use a random block design, which involves setting up all turbines in the study identically, but (typically) running half the turbines as test and the other half as control, on any one night. This can remove some (but not all) of the uncertainties associated with fixed turbine locations and/or bat migration routes.

Understanding the power of a mortality study during the study design phase is critical as a mortality study is often multifaceted, time-consuming, and expensive. A mortality study of high statistical power can yield statistically significant results that may allow definitive decision-making.

NRG has been a participant in approximately eight mortality studies. As of this writing, only one has publicly available results. Test groups for these studies range from four turbines to more than forty, with the average size being around twelve. There are at least two other mortality studies published using non-NRG deterrents.

Pros	Cons
Models the PCM already in place	**Acknowledges there will be bat mortality within control group**
Precedence of peer review	**Depending on size, searching can be very expensive**
Statistically significant results	**Do not know how many bats were in the area**

Published examples of bat deterrent studies using mortality monitoring:
Weaver, SP., Hein, CD., Simpson, TR., Evans, JW., Castro-Arellano, I. (2020). Ultrasonic Acoustic Deterrents Significantly Reduce Bat Fatalities at Wind Turbines. *Global Ecology and Conservation*, 24: e01099.

Study design: Sixteen turbines in random block design, meaning the systems were installed on all sixteen turbines, but on any given night, only eight were running the deterrent.

Duration: Study ran for two full bat seasons. All plots inspected daily after treatments.

Statistics: Enough total carcasses were recovered that the study could present statistically significant results at the 95% confidence level for all bats, and at the species level for Brazilian Freetail and Hoary bats.

Video / Thermal Study

A video or thermal study offers visual evidence of bats in the turbine area. This is advantageous over a mortality study in that a viewer can observe how a bat is behaving, and whether it is within the rotor-swept area (depending on the number of cameras used). It is also possible to run this type of study without the need for a control group, therefore reducing the potential for mortality during the study period.

The power of a thermal study can be maximized by adding more cameras, increasing the number of turbines being observed, and running the study over a greater period.

A video study can become complex very quickly. Since a wind turbine can yaw, or turn to point into the wind, and the blades are very long, the amount of airspace needing to be measured can be exceptionally large and may exceed the range and/or field of view of many cameras. To get accurate 3D measurements, a minimum of two cameras must be used. The post-processing data analysis can also pose a significant challenge due to sheer size, as terabytes of data are often involved.

NRG is aware of three thermal studies involving its Bat Deterrent System, one of which has publicly available results. Test groups for these studies are typically small, consisting of one to three turbines.

Pros	Cons
Visual confirmation of bat behavior	**Significant amount of data post-processing**
Reduced mortality during trial period (vs. mortality study)	**Potential to generate TBs of data to review**
	Unlikely to determine bat species

Published examples of bat deterrent studies using video or thermal monitoring:
Technical Report: Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent in Reducing Bat Fatalities at Wind Energy Facilities, 2020.

Study design: Four turbines selected (of sixteen turbines also in a mortality study).

Duration: 112 nights, two turbines per night.

Acoustic Monitoring

An acoustic monitoring study involves the use of strategically placed microphones to monitor bat activity. In many cases, a single microphone is placed on the nacelle of a turbine to listen for bats. It may be possible to improve the effectiveness of the study by increasing the number of microphones deployed per turbine. Recordings from the microphones are run through advanced data processing algorithms that can determine, with a high degree of accuracy, the species of the bats in the area. This can be of significant benefit to the study, as neither thermal nor mortality studies provide insight into the bat species present around the turbine.

Two major drawbacks exist, however. Scientists have determined that some bats may not be echolocating all the time [Chiu, C, 2008]. If they are not echolocating, they will not be recorded by the microphones, and thus excluded from the data collection. The other drawback is sound attenuation. High frequency sound attenuates quickly in air, so depending on the bat species, some bats more than 30m away from the detector may not be recorded [Voigt, C.C, 2021].

It should also be noted that NRG's Bat Deterrent System operates within the same ultrasonic frequency range as most bats. If the microphones are near the deterrent system, the deterrent system will overwhelm the acoustic data collectors. It may be possible to perform advanced data processing to remove the noise of the deterrents.

NRG is aware of two acoustic studies, one of which has publicly available results. Test groups for these studies are typically small, consisting of one to three turbines.

Incidentally, some smart curtailment systems will rely on an acoustic sensor; many of the drawbacks to acoustic monitoring for a study also apply to the use of an acoustic sensor to inform a smart curtailment regime.

Pros	Cons
Reasonably good species identification	**Scientists now believe bats may not echolocate all the time**
Reduced mortality during trial period (vs. mortality study)	**Distance between bat and detector is limited**
	Potential to generate GBs of data to review

Published examples of bat deterrent studies using acoustic monitoring:
Bronckers, S., Clignet, A., De Zutter, C., Martens, J. *Deterrent System Saving Bats Around Wind Turbines Sounds Positive*.

Study Design: One turbine.

Study Duration: One season.

Conclusions

Taking the time to evaluate the need for a study design and how it will be executed is important for any wind project. While there is no perfect study design, carrying out a validation study of high statistical power can provide invaluable insight into how effective NRG's Bat Deterrent System will be at protecting bats at a given wind site. A well-designed and executed study should yield actionable information that will allow a wind farm owner to make decisions about the investment in technology for their wind farm, while also demonstrating that the solution is protecting bats.

For more information about NRG Systems or its Bat Deterrent System, please contact bats@nrgsystems.com.

References

Chiu, C., Xian, W., Moss, CF. (2008). Flying in Silence: Echolocating Bats Cease Vocalizing to Avoid Sonar Jamming. *PNAS*, 35: 13116-21. https://doi.org/10.1073/pnas.0804408105.

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Voigt, C.C., Russo, D., Runkel, V. and Goerlitz, H.R. (2021). Limitations of Acoustic Monitoring at Wind Turbines to Evaluate Fatality Risk of Bats. *Mammal Review*, 51: 559-570. https://doi.org/10.1111/mam.12248.