A big brown bat. *Photo from Getty Images 485010942*

Using Ultraviolet Light To Deter Bats From Wind Turbines—Short Science Summary

Summary

One hypothesis seeking to explain why bats collide with wind turbines is that bats, while relying on visual cues during open-air flight, mistake turbine silhouettes as trees. As a result, bats become attracted to the wind turbine in anticipation of foraging, roosting, and/or mating opportunities. As a technique to disrupt this attraction, a series of studies (including ongoing research) have investigated whether illuminating wind turbines with ultraviolet (UV) light (visible to bats but not humans) would make them visually distinct from trees to the point that bats would no longer confuse the two. During tests in a natural setting, bats appeared to exhibit a slightly negative response to UV-lit trees; however, during testing at wind turbines, there was no significant difference in bat activity between UV-lit and non-UV-lit turbines. At present, there is no strong evidence that UV illumination either deters (or attracts) bats, and existing evidence remains inconclusive. Current and future research should investigate the efficacy of UV illuminance with study designs that focus on increased sample sizes while monitoring for any potentially unanticipated negative effects to the environment when adding stimuli such as UV lights, which may, for example, attract insects.

Background

While wind energy is a major component of the carbon-free energy transition, the construction and operation of wind energy turbines are not without environmental effects. In North America, several bat species collide with operating turbines. Observational studies have documented bats interacting with wind turbines for extended periods of time (e.g., approaching turbine structures repeatedly or flying around the rotor swept area for seconds up to minutes at a time), suggesting that bats may be attracted to turbines. Of the numerous hypotheses of why bats may approach and interact with

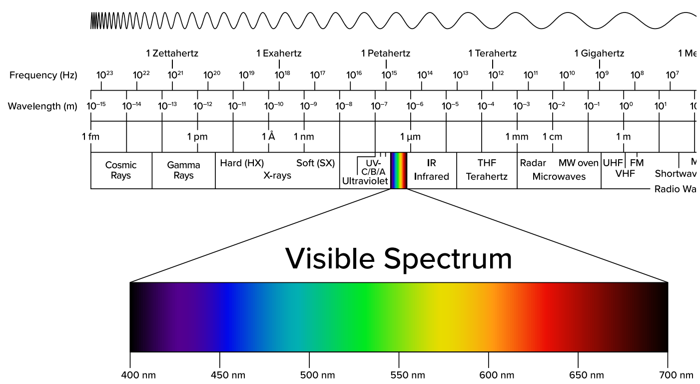

Figure 1. The electromagnetic spectrum.
Image from Getty Images 2152966948

wind turbines, one involves the potential attraction of bats to visual cues (e.g., aviation lights) produced by wind energy facilities (Kunz et al. 2007; Cryan and Barclay 2009; Guest et al. 2022; Jonasson et al. 2024).

Though bats are often best known for their ability to use echolocation (i.e., ability to assess the environment by emitting sounds and listening to echoes reflected off objects), they also rely on vision during open-air flights. Bats can see in dim ambient light conditions and are able to see wavelengths from 360 to 680 nanometers (nm) (Mistry and McCracken 1990; Müller et al. 2009) (Figure 1). Bats can see large objects at distances greater than 2 kilometers in low-light conditions (compared to <100 meters when using echolocation) (Boonman et al. 2013). Further, vision may be prioritized over echolocation when visual cues are more reliable than acoustic ones. For example, when bats exit a tree hollow or cave, light can be a more reliable cue than echolocation, especially when dozens or millions of other bats are exiting at the same time, masking returning echoes.

One hypothesis explaining visual attraction to wind turbines is that certain species of bats mistake turbine silhouettes as a potential resource and move toward them in pursuit of resources such as prey, roosts, and mates. Assuming bats mistake wind turbines for resources associated with trees, Gorresen et al. (2015b) proposed illuminating turbines to reduce the visual contrast of their dark silhouettes against the relatively lighter sky backgrounds, thereby decreasing visual similarities to trees and reducing bat activity. Given that bats can see into the UV spectrum, beyond human vision, the authors proposed illuminating the turbines with UV light to avoid visual impacts while still disrupting attraction.

Studies Investigating UV Light To Reduce Bat Interactions

A series of three studies, Gorresen et al. (2015a, 2015b) and Cryan et al. (2021), investigated the use of UV light as a technique to disrupt resource-based attraction. These studies discussed bat behavioral responses to UV light in a controlled experimental setting, in a natural setting, and at a wind farm. Specifically,

- Gorresen et al. (2015a) ask how widespread dim UV vision is in North American bat species.
    - Findings: Bats can see, and may move toward UV illumination (termed an "escape toward the light response").
- Gorresen et al. (2015b) ask if UV-lit trees elicit behavioral responses from free-flying bats.
    - Findings: Bats exhibit a weak but significant negative response to UV-lit trees. Insects exhibit a relatively strong preference for UV-lit trees.
- Cryan et al. (2021) ask if UV-lit wind turbines are less attractive to bats.
    - Findings: There was no significant statistical difference in bat activity between UV-lit turbines and non-UV-lit turbines.

Gorresen et al. (2015a)—Bats See UV, But How Widespread Is Dim UV Vision in North American Bats?

Recent studies demonstrate that some species of bats have UV-tuned photoreceptors (Müller et al. 2009) and further exhibit behavioral and physiological responses to UV light in laboratory settings (Müller et al. 2009; Xuan et al. 2012). Building on these earlier findings, Gorresen et al. (2015a) catalogued the prevalence of UV vision among bats in North America. The researchers tested the behavioral responses of 512 wild-caught bats (covering seven species and three families) to UV light. To test if bats could see the light, the research team used a crawling Y-maze apparatus. The Y-maze test is a common method to assess animal choice, whereby animals are presented with a "fork-in-the-road" decision. Bats were released in the main stem of the Y-maze and crawled toward the point where the main stem split into the two branches of the "Y." Once each bat arrived at the split, they had to choose to exit the branch on the right or left. The end of one arm of the Y-maze was illuminated with dim UV light (peak wavelength of 365 nm), whereas the other was dark. The researchers expected bats to favor exiting the UV-lit arm of the Y-maze. All seven species showed a statistically significant "escape-toward-the-light" response, suggesting that bats can see and show a proclivity toward dim UV light.

How might UV vision be relevant to bats?

UV light comprises the range of wavelengths between 0 and 400 nm. Bats have documented visual acuity between 360 and 400 nm. It remains unclear if UV vision in bats is adaptive to nocturnal life or if the ability to see into the UV spectrum is an ancestral trait with no current adaptive value. The ability to see UV light may be advantageous for nectar-feeding bats that forage on UV-reflecting flowers, but it is unclear what adaptive advantages may be relevant to bats that forage only on insects.

Gorresen et al. (2015b)—Do UV-Lit Trees Elicit Bat Behavioral Responses?

Building on the evidence that bats see and respond to UV light, Gorresen et al. (2015b) conducted a field experiment focusing on Hawaiian hoary bats (Lasiurus cinereus semotus), an endangered subspecies of the mainland hoary bat (Lasiurus cinereus cinereus) known to be struck by moving wind turbine blades. The researchers illuminated trees with dim UV light and compared the activity of free-flying Hawaiian hoary bats and insects when trees were UV-lit and when they were not. Using acoustic detectors and thermal video cameras, the researchers quantified bat activity from 10 sample sites with 2 nights of control (n = 20) and 2 nights under treatment conditions (n = 20). The presence of dim UV light did not result in complete inactivity of bats, but their results suggest a small but statistically significant decrease in bat activity near UV-lit trees. Insect activity increased at UV-lit trees.

Cryan et al. (2021)—Do UV-Lit Wind Turbines Deter Bat Activity?

Cryan et al. (2021) conducted a proof-of-concept study testing the application of dim UV lighting on operating wind turbines to determine if the slight decrease in bat activity rates observed by Gorresen et al. (2015b) could be replicated. The objective of this study was to assess whether bat activity, and presumably bat fatality, at wind turbines would be reduced by illuminating turbines with dim light. The authors outfit two turbines with 12 UV lights mounted equidistant around the monopole 20 meters above ground (Figures 2 and 3). Each night, the study alternated between having the wind turbines lit and unlit. Bat activity for UV treatments were mixed, and the low sample size made it impossible to detect differences statistically. However, there was a slight increase in the number of bat activity events and the cumulative duration of detections on nights with UV treatment.

Figure 2. Light arrays being positioned below the sweep of wind turbine blades. *Photo from Paul Cryan, USGS*

Figure 3. UV illuminator unit magnetically attached to wind turbine monopole. *Photo from Paul Cryan, USGS*

Related Research: Young et al. (2003)

Investigating avian responses to UV-reflective wind turbine coatings, Young et al. (2003) conducted carcass surveys at turbines painted with UV-reflective paint (~60%) and turbines painted with less-UV-reflective paint (~10%). Though the study focuses on avian responses to UV reflectance, the authors note that, in addition to avian carcasses, searchers found 75 bat carcasses, with 61 bat carcasses found at UV-reflective turbines and 12 at non-UV-reflective turbines. Hoary bat was the most common species observed (63 fatalities). The observed fatality rate (carcasses/turbine/search) for the UV-reflective turbines (0.045) was more than twice that of the less-UV-reflective turbines (0.019) but not statistically different ($p > 0.05$). It may be relevant to note that the carcass search interval was 28 days, which is longer than would be typical if the searches had focused on bats, as bat carcasses do not last on the landscape as long as those of birds, which can be more easily identified over longer periods of time from feathers left near carcasses that predators typically do not consume.

Remaining Gaps

We currently lack an understanding of how bats will respond to UV light cues in natural settings. This is due in part to not understanding if insectivorous bats use their UV visual acuity in natural settings or if such visual capabilities are simply evolutionary holdovers. Gorresen et al. (2015b) note small sample sizes and large differences in the amount of bat activity between trees in their Hawaiian study. As such, it would be valuable to replicate the study with an increased sample size and study duration. If successful, replicating the study at sites throughout North America would be a valuable demonstration of UV deterrent efficacy prior to wind farm application.

It is interesting to note that the attraction these bats exhibited resembled an "escape-toward-the-light" response. If we expect bats near wind turbines to be in an escape-type behavioral mode, then perhaps these results suggest that bats would be attracted to UV-lit turbines. More research is needed to determine under what conditions we expect bats to escape toward the light and under what conditions we expect them to be deterred. Voigt et al. (2017) tested the effects of green light-emitting-diode lighting along a migratory corridor adjacent to the Baltic Sea. The researchers found that the two most abundant migratory species in the region increased activity by 50%, but with both migratory and nonmigratory species, bat activity was unaffected by the light, suggesting species may respond to artificial lighting at night depending on their ecology.

The reasons why bats interact with wind turbines remain unknown. Cryan et al. (2021) advise caution when trying to manipulate bat behavior at wind turbines, particularly when adding additional stimuli such as lighting to the environment that may have undesired effects on nontarget organisms such as insects. It is crucial to quantify any potential effects to insects, a taxonomic group already affected by turbines (Voigt 2021), to disentangle how insect behavior in proximity to turbines could influence bat behavior. For instance, aggregations of insects at wind turbines might attract nearby bats toward turbines for opportunistic foraging. Insect attraction to turbines could provide a realized resource that bats begin to associate with desirable habitat as a learned response. This possible outcome highlights the importance of longer-term studies that can capture learned behaviors that may change over time.

Recommended Next Steps

Priority areas for further research and key considerations include:

- More rigorous testing in controlled settings with bats that are in the same physiological states as those that bats are in during the fall, when collision risk is greatest.
- Experimental assay designs that allow for greater control of light ranges and flicker rates and give individual bats the opportunity to respond to UV light when they are in flight rather than crawling.
- Consideration of the effect of potentially attracting insects toward turbines with UV lights.
- Focus research on identifying drivers of interactions, which will enable cost-effective solutions and shorten the timeline to identifying and implementing sustainable solutions. This is preferable to testing a single intervention at a time, which may also lead to inconclusive results and require repeated testing.

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