The Likelihood of Bats Experiencing Barotrauma Near Moving Wind Turbine Blades

In October 2018, the International Energy Agency Wind Task 34—Working Together to Resolve the Environmental Effects of Wind Energy (WREN)—organized a virtual forum to discuss the likelihood of bats experiencing barotrauma when flying near moving wind turbine blades. The forum included experts in bat biology and physiology, bat and wind turbine interactions, wind turbine technology, and atmospheric sciences. This educational brief summarizes the discussion during the forum and written comments from those who could not attend. Relevant literature was used to provide additional context when needed.

SUMMARY

Possible explanations regarding the direct cause of bat mortality at operating wind turbines are (1) blunt force trauma caused by turbine blades striking individual bats, often referred to as collisions, and (2) barotrauma, resulting from exposure to pressure changes located near the surface of moving wind turbine blades. While collision-related mortality is easily understood, the mechanism causing barotrauma is more complex. Fast-moving wind turbine blades create regions of high- and low-pressure variations along the blade surfaces. If bats fly within these regions, the rapid change in pressure may cause internal bleeding, damage to lungs or other organs, and damage to the inner ear. However, sufficient data demonstrating barotrauma as a common cause of bat mortality at wind turbines are lacking. Moreover, the pressure variation necessary to cause barotrauma in bats is so close to the surface of turbine blades that there is a higher probability of direct contact with the blades than of solely experiencing barotrauma. Regardless of the cause, bats are interacting with fast-moving wind turbine blades, and these interactions are resulting in fatalities. Resolving this issue will require a better understanding of bat behavior and cost-effective measures to reduce interactions between bats and wind turbines.

A Hoary bat. *Photo by Cris Hein, National Renewable Energy Laboratory*

THE STATE OF THE SCIENCE ON BAROTRAUMA

In 2008, initial evidence supporting barotrauma as a cause of bat mortality at wind turbines found that 57% (n = 43) of bat carcasses collected under wind turbines showed signs of internal bleeding with no indication of external injury or blunt force trauma. Results from a subsequent study showed that 37% (n = 54) of all recovered bat carcasses had internal injuries consistent with barotrauma but lacked external injury. Additional studies have noted some bat carcasses with internal bleeding and no apparent external injury, but small sample sizes limit broader inference. It has also been suggested that barotrauma may result in delayed or sublethal mortality. Delayed mortality may result if bats are exposed to the rapid pressure change but are able to fly outside of the wind farm before they succumb to their injuries. Sublethal barotrauma may damage the inner ear, specifically the eardrum, which may reduce survivability by impacting the ability of bats to echolocate, a critical function for navigation and foraging. In such cases, individuals would not be represented in mortality estimates at wind energy facilities, resulting in underestimates of cumulative mortality.

To further investigate the reported number of bat carcasses lacking external injuries, one study used radiology to identify bone fractures that may have gone unnoticed by visual inspection alone. Radiographs showed that 74% (n = 29) of bat carcasses had at least one broken bone. Visual inspection found 33% fewer bone fractures than radiographs, indicating that visual inspection may be significantly less effective at identifying collision-related mortalities. Moreover, the criteria often used to indicate barotrauma, including fluid in the lungs and internal bleeding, can result from collision events. Additionally, characteristics such as time of death, environmental temperature, and freezing of carcasses for later research are known to cause postmortem morphological changes, which may resemble symptoms of barotrauma. An experiment used a controlled

A silver-haired bat. *Photo by Cris Hein, National Renewable Energy Laboratory*

Figure 1. Low-pressure regions on the downwind side of the blade and high-pressure regions on the upwind (blade surface) side are caused by local flow accelerations. Vortices also form downwind from the blade tip. These can cause barotrauma in bats. *Graphic from Lawson et al. 2010. An Investigation Into the Potential for Wind Turbines To Cause Barotrauma in Bats. PLoS ONE 15(12): e0242485.*

environment to monitor the decomposition of bat carcasses and found that levels of fluid in the lungs and excess fluid in blood vessels significantly increased in as quickly as 2 and 24 hours, respectively, concluding that barotrauma diagnoses through recovered bat carcasses are likely unreliable. Therefore, injuries from collisions and changes caused by decomposition may be misdiagnosed as barotrauma.

The location of carcass recoveries relative to the base of the turbine may also artificially inflate the proportion of carcasses identified as having succumbed to barotrauma. Bat carcasses classified as succumbing to barotrauma or individuals with fewer broken bones were located closer to the base of wind turbines compared to bats with obvious external injury. This, combined with the idea that bats being struck by blades, particularly under high-wind-speed conditions, may propel individuals to greater distances away from the wind turbines suggests the potential for a higher likelihood of individuals with visually obvious external injury to be unaccounted for in carcass surveys and therefore underrepresented.

An analysis using computational fluid dynamics simulations and analytical calculations of blade-tip vortices estimated the pressure changes bats may experience when flying near moving turbine blades. Because there are no laboratory data on the impacts of pressure changes on bats, the results of the study used data from rats and mice as surrogates. Two fields of pressure are generated by the moving blades: (1) a low pressure field on the downwind side, and (2) a high pressure field on the upwind side (Figure 1). The results showed the low pressure change that bats experience near moving blades is nearly 8 times less than the pressure that causes mortality in rats. The high pressure change experienced near the moving blades is approximately 80 times less than the exposure level that causes 50% mortality in mice. The study concluded that high- and low-pressure variations are extremely localized and that bats must take an improbable flight path that skims the surface of the blade to experience barotrauma. The slightest change in flight path either results in a collision or experiencing a harmless pressure change.

Physiological differences between bats and rodents make direct comparisons difficult. For example, bats have a thin blood-gas barrier and other flight adaptations that may make them vulnerable to smaller pressure changes compared to other mammals. However, the pressure changes necessary to cause barotrauma are so close to the surface of the turbine blades, that it is unlikely that a bat could experience barotrauma without also being struck by the moving turbine blade.

CONCLUSION

The discussion of whether bats succumb to barotrauma has persisted since 2008. Conflicting evidence makes it difficult to assess the extent and magnitude of this phenomenon. Conclusive evidence regarding the plausibility of barotrauma may not be possible. Research investigating bat response to pressure variations comparable to those that occur on the surface of wind turbine blades has ethical implications (i.e., subjecting live bats to lethal pressure changes). In addition, cost-effective analyses to differentiate between blunt force trauma and barotrauma in carcasses may be unrealistic due to the nature of post-construction monitoring and field research. Regardless of the cause of mortality in bats from wind turbine interactions, addressing the estimated hundreds of thousands of bat fatalities per year requires reducing interactions between bats and rapidly spinning wind turbine blades. This may be achieved by gaining a better understanding of why bats approach and interact with wind turbines, limiting bat activity near wind turbines using deterrents, and curtailing wind turbine blades when collision risk is high.

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