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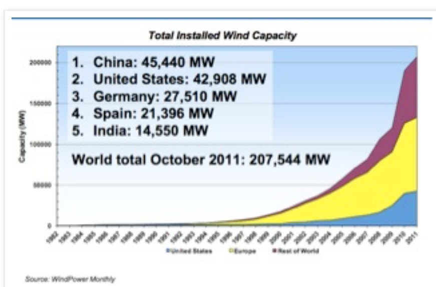
Why Bats Can't See Wind Turbines

A blog about wind energy and its ecophysiological impacts to bats

by David Gallagher

What is the Problem with Bats and Wind Turbines?

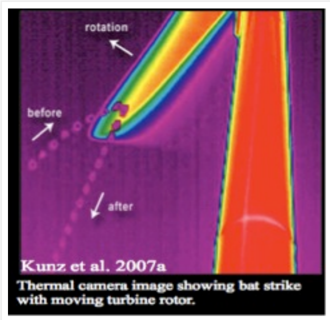
If you have driven over Tehachapi Pass on Highway 58, you probably could not have helped but notice the 500 or so wind turbines that dot the ridges. These turbines make-up the Alta Wind Energy Center, the largest wind farm in the United States at 1,320 Mega-Watts. Wind energy in the United States and around the world is expanding quickly.



In 2003, an estimated 4000 bats were killed at the Mountaineer Wind Energy Center in West Virginia. Follow-up studies confirmed bat mortalities were taking place at other wind energy sites around the United States. Since there is no systematic program in place for monitoring bat fatalities in the United States, it is impossible to know how many bats are being killed annually. However, it has been estimated that up to 100,000 bats will be killed at wind energy centers by 2020 in the Mid-Atlantic Highlands alone. Currently, wind energy represents a significant human-induced impact to bats.

Why is this magnitude of bat mortality a concern? Bats play a critical role in ecosystems. They are predators of insects, prey to other vertebrates, pollinators, and seed dispersers. A recent analysis suggests that a continued loss of bats could result in agricultural losses of $3.7 billion/year in the United States.

Of the 45 species of bats that occur in North America, 11 are experiencing fatalities at wind energy centers. The majority of the bat fatalities are migratory tree-roosting bats, including the hoary bat (*Lasiurus cinereus*) and eastern red bat (*Lasiurus borealis*). High rates of mortality have also been recorded for non-migratory bats, including the little brown bat (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*). All these bats are in the sub-order Microchiroptera (microbats) and are characterized by the use of echolocation. The two primary causes of bat fatalities at wind energy centers are direct collision and barotrauma, both from rotating blades (rotors). Barotrauma is the mechanical damage to lungs and other organs caused by a rapid change in pressure. Since turbine blades are equivalent to an airfoil (think airplane wing), they create a pressure differential in the surrounding environment. Bats are killed when they fly through the area of pressure change. Most bat fatalities occur on low-wind nights and consequently low rotor speeds and analyses show that the interactions with the wind turbines are not random. Bat mortality associated with wind turbines is puzzling given that bats have the ability to echolocate and generally have excellent nocturnal vision.



How does echolocation work?

Echolocation is a complex process that has given bats the ability to exploit the night sky in the search for insects. Echolocation is the analysis of echoes from emitted sound waves. Bats use echolocation to construct a sound-picture of their immediate environment. The process is analogous to the use of SONAR by the US Navy to detect objects or features underwater. Bats emit calls through the mouth or the nostrils. Those using nostrils have complex folds of skin and cartilage known as noseleaves. Noseleaves act as an acoustic lens, focusing the sound in front of the bat. Microbats have to hear well and have large external ears, called pinnae. They may also have a tragus, a cartilaginous projection from the base of the ear. The presence of the tragus improves the sensitivity to the echoes. Bats acute hearing is necessary so that they can detect the weak echoes, but that sensitivity is a liability because the sound pressure of an echolocation pulse can be 120 decibels (dB). A decibel is a measure of the intensity of a sound. The sound intensity of an echolocation pulse (at 120 dB) is equivalent to the sound intensity of a jet taking off. Some bats make themselves temporarily deaf when emitting an echolocation pulse in order to avoid damage to their hearing.

A diagram showing the echolocation pulses (white) and the echoes (yellow)

Notice the large ears (pinnae) and the structure at the base of the ear (tragus)

Most bats use high frequency pulses (14KHz – 100KHz) for echolocation. The top-end of human

venomous...

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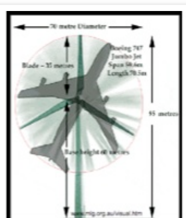
hearing is around 20kHz. There are several advantages to using high frequencies. The first is the fact that few other natural sounds are so high, thus eliminating possible interference. The second is that high frequency sounds are rapidly attenuated (reduced in amplitude) in the air and rarely have a range of greater than 30 meters. This characteristic may be a way to keep interference to a minimum from the echolocation pulses from other bats. The third advantage is that most microbats catch small insects, which require high frequency, short wavelength (3-30 millimeters (mm)) pulses to detect. You might recall that wavelength and frequency are inversely proportional to one another. A good way to think of how this works is to consider an insect that is 3mm in diameter and if a bat emitted a pulse of 30mm, the insect could easily not be detected because it would “fall” into the crests or troughs of the wave. As if this was not complex enough, echolocation pulses fall into two categories, frequency modulated (FM) and constant frequency (CF). Most microbats use a combination of both types to paint a sonic picture of their environment. Since bats detect objects in their surroundings by listening to the echo of each emitted pulse, they need to be able to vary the frequency (frequency modulation) and duration of the emitted pulse to accurately determine distance, elevation, and shape of the object. FM calls are generally 0.2-5 milliseconds (ms) long. Here is an example of why these pulses need to be short: If a bat detects an object 3 meters away and the echo returns in 5ms after the emitted pulse and the emitted pulse was more than 5ms long, the bat would be listening to the echo before it had finished emitting the pulse. Since sound waves always travel at the same speed though air, a bat can determine the pulse-delay of an echo and calculate the distance to the insect. Bats that use CF pulses exploit the Doppler effect and are generally 10-100ms long. You might remember the classic example of how the pitch of a siren on a fire truck becomes higher as it gets closer, and then the pitch decreases as the fire truck passes. This is the Doppler effect. As the fire truck approaches, the sound waves from the siren are pushed against your ears due to the motion of the vehicle. The waves become compressed thus decreasing wavelength. When wavelength decreases frequency (pitch) goes up. This is a form of frequency modulation. The moving wings of an insect cause frequency modulation of an echo from an echolocation pulse through the Doppler effect. Bats can be extremely sensitive to these frequency modulations. By using both FM and CM components in echolocation, bats can resolve amazing details in their immediate surroundings.

Why does a bat collide with a rotating turbine blade in the first place?

Research has revealed, using simulations, two interesting characteristics of a moving turbine blade. The first is that a moving turbine blade (approximately 6m/s) will cause a frequency modulation of an echo that is similar to the movement of an insect’s wing. The Doppler effect frequency shifts associated with the blades are up to 7%. Because of the small frequency shifts, bats may need 50-300 echoes to paint an accurate picture of a moving turbine blade. It has been shown that the big brown bat can only detect frequency shifts greater than 8% when using FM echolocation. Bats that employ mainly FM calls cannot accurately compensate for these small Doppler shifts (with less than 50 echoes) resulting in miscalculated distances and speeds of the rotor blades. Given the combination of blade speed, the range limit of echolocation, a short approach time and the need for many echo returns, a bat simply may not have enough time to see what is coming at it.
The second characteristic of a slow moving turbine blade is that it produces variable intensities on returned echoes (echo amplitude). These changes in echo amplitude are also seen in the echo returns from the fluttering of insect wings. It is possible that bats misinterpret these echoes as prey and approach the blades to investigate. It is interesting to point out that stationery blades and higher turbine blade speeds cause significantly less fatalities. These results are intriguing because it suggests that bats can see a turbine blade, but they may not be able to properly calculate its speed and distance, resulting in a collision or barotrauma.



Schematic to illustrate the size of a modern wind turbine compared to a 747 jet

Why are Bats Initially Attracted to Wind Turbines?

There are several hypotheses that address the question of why bats are attracted to wind turbines in the first place. The first is that wind turbines built in forested areas create edge habitat when trees are removed to make space for the turbines. Bats are known to use edges for travel and foraging. The second is that bats may perceive turbines as roost sites, and the third is that insects have been shown to congregate around the tops of the turbine towers. Since bats eat insects, they will actively forage near the turbines.

A Final Word on Bats and Wind Energy

The ability to echolocate is a tremendous physiological adaptation and is a highly evolved complex mechanism. Even though bats posses a highly refined ability to detect objects in the night sky, there unique sense of perception was not designed to detect and evade a rotating blade that sweeps an area the size of a 747 jet. It is important to develop and implement alternative energy sources but it also equally important to investigate and mitigate for ecological impacts associated with alternative energy. Additional research needs to be conducted to better ascertain the relationship between bat ecophysiology and wind turbines. I leave you with a picture of the Alta Wind Energy Center in Tehachapi Pass.

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Posted by Calpoly Bioblog at 9:51 PM

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2 comments:

Ryan Baker-Branstetter January 29, 2013 at 5:58 PM

This was fascinating! It helped fill in a lot of the details as to why bats have such as issue with wind turbines, and I thought it was particularly interesting that high speed blades caused lower fatalities that those that we slow moving. Have there been any developments with high frequency sound emitters that only bats could hear that would possibly keep them away from the turbines? Very cool stuff David!

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Blogger December 1, 2016 at 1:51 AM

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