Ultrasound emissions from wind turbines as a potential attractant to bats: a preliminary investigation

Principal Investigator
Joseph M. Szewczak, Ph.D.
Humboldt State University
Arcata, CA 95521

Co-Investigator
Ed Arnett
Bat Conservation International
Austin, TX 78716

1 May 2006

Foote Creek Rim wind facility, Arlington, WY

Summary

Although audible acoustic emissions from wind turbines have been extensively measured (i.e., frequencies below 20 kHz), the ultrasound emissions remain uncharacterized for most wind turbines. We performed a basic characterization of ultrasound emissions from a variety of wind turbines to determine whether ultrasound emissions may contribute to attracting bats toward wind turbines with consequential fatalities from rotor strikes. We were particularly interested in characterizing ultrasound emissions from the 1.5 MW NEG Micon turbines because of the documented bat mortality from these turbines operating at the Mountaineer Wind Energy Center in West Virginia. All turbines sampled generated only minor ultrasound above ambient sound levels. The majority of acoustic energy was emitted at audible frequencies and trailed off rapidly above audible frequencies with a similar profile to that of ambient wind noise. Measured from ground level, 34 m directly below the 1.5 MW NEG Micon wind turbine rotors, these turbines emitted approximately 5, 3, and 2 dB above ambient at 20, 30, and 40 kHz respectively. Above 50 kHz there was no significant difference from ambient sound levels. We conclude that ultrasound emissions, as measured from the ground-level, from these wind turbines do not likely play a significant role in attracting bats. However, ultrasound could be emitted from other turbines we did not measure during this preliminary investigation, or from the nacelle of turbines, possibly warranting further investigation.

Introduction

Widespread and extensive documentation of bat mortality at wind energy facilities has prompted concern and subsequent investigations of the magnitude and causal factors of this mortality. In response to documented bat mortality from turbine rotor impacts at the Mountaineer Wind Energy Center in Tucker County near Thomas, West Virginia, and at the Meyersdale Wind Energy Center in Somerset County near Meyersdale, Pennsylvania (Arnett 2005), we undertook a preliminary investigation to determine whether turbines in service at these sites may be emitting ultrasound (sound inaudible to humans, but audible to bats) that might potentially attract bats to these hazards.

Ahlen (2003) suggested that audible “swooshing” sounds generated by moving turbine rotors may attract bats. Unfortunately, if audible swooshing sounds attract bats, there may be only limited opportunity to reduce or eliminate it as an attractant. However, bats also may be attracted to ultrasound, if present. In fact, ultrasound broadcasts are under investigation for their potential to attract bats over agricultural fields. Audible sound emissions from turbines have been measured, mostly in regard to meeting regulatory standards for noise. However, the ultrasound emissions of most wind turbines remain uncharacterized. If present, it may contribute to attracting bats to the hazard of moving rotors, and if so, characterizing any such ultrasound emissions may provide an avenue for eliminating or attenuating this potential attractant.

To attract bats at a distance and draw them into the turbine rotors, any ultrasound emissions would have to be of sufficient amplitude to be audible to bats at a distance greater than the length of the rotors. If present, ultrasound of this amplitude would be audible at ground level below the rotors. This facilitated this preliminary assessment in which we were restricted to measurements at the ground-level near turbines. If substantial ultrasound emissions can be detected from turbines at the ground-level, then it can be assumed that these structures emit high amplitude ultrasound, and this would warrant a more thorough investigation subsequent to this investigation. It is possible that there may be ultrasound generated in the mechanisms and electronics within the turbine nacelles that we could not detect from ground level. But if present and indiscernible at ground level, then any such ultrasound would likely not contribute to attracting bats at a distance, although it could contribute toward promoting investigatory behavior once within striking range of turbine rotors.

Study sites and methods

From June to August 2005, we visited six wind turbine sites and recorded ultrasound from seven different types of wind turbines (Table 1). The Neg Micon 1.5 MW turbines are of particular interest because they are the type of turbine in service at the Meyersdale, PA and Mountaineer, WV facilities documented to cause significant bat mortalities (Arnett 2005).

Table 1. Wind turbine sites and wind turbines visited for sound recording.

Site	**turbine**
National Renewable Energy Laboratory, Golden, CO	AOC1550
Foote Creek Rim, Arlington, WY	Mitsubishi 600 kW Neg Micon 750 kW
Rock River, Laramie, WY	Mitsubishi 1 MW
Medicine Bow, WY	Vestas 660 kW Clipper 2.5 MW
Kimball, NE	Neg Micon 1.5 MW

We recorded 3.4 second samples of full spectrum ultrasound using a handheld Pettersson D240x ultrasound detector (Pettersson Elektronik AB, Uppsala, Sweden) that enabled power frequency analysis of the ambient sound and sounds generated from the turbines (Fig. 1). This unit sampled at 307 kHz with 8 bit resolution. The recordings were saved to computer as wav files using SonoBat (DNDesign, Arcata, CA) by playing them back from the detector at a time expansion factor of 10 into an onboard laptop computer sound card that resampled at 44.1 kHz and 16 bit resolution to retain the full signal quality of the original signal. The uppermost frequency resolvable was 154 kHz. Ambient sound was recorded at the turbine sites at sufficient distance from the turbines where audible sounds (by ear) from the operating turbines were undetectable above ambient sound (approximately 100 m from the base of the turbines).

The frequency vs. power spectra plots presented in the results that follow were generated using a custom routine coded in LabVIEW (National Instruments, Austin, TX). This routine processed power spectra using a fast Fourier transform from consecutive 4,096 point sections (0.0929 second) of each file and averaged the results of the approximately 360 sections from each file. Power was scaled to decibels (dB), however the equipment used in this study limited our results to only relative dB between ambient sound and sound recorded near the turbines and equipment. Sonograms were generated using SonoBat (DNDesign, Arcata, CA).

Fig. 1. Recording ambient sound (left) and sound at base of an operating wind turbine, directly below the rotors. The photographs show recording settings. During actual recording, the detector was held just in front of the chest at about sternum level, back to the wind, to shield the microphone element from direct wind noise (photos by Joe Szewczak, Humboldt State University).

Results

Results are listed by site visited.

National Renewable Energy Laboratory, Golden, CO

The winds were light during our site visit at the National Renewable Energy Laboratory (NREL) which limited our recording to a single turbine that could be electrically rotated for testing, the AOC1550. Compared to other turbines tested, the rotating blades of this turbine emitted sound up to 15 dB above ambient (Fig. 2). However, with the light winds during this recording the ambient noise level was also low, which would artificially enhance the relative difference compared to the other turbines we recorded driven by the wind. The rotating blades of this turbine generated no detectable ultrasound above 30 kHz. There was minor ultrasound generated from 20–30 kHz that exceeded ambient levels (8 dB maximum above ambient).

The control electronics of the AOC1550 did generate substantial ultrasound, peaking at 50 dB above ambient recorded 10 m from the source (Figs. 3 and 4). The frequency distribution of the power in these emissions was non-uniform, with a peak in power at 40 kHz.

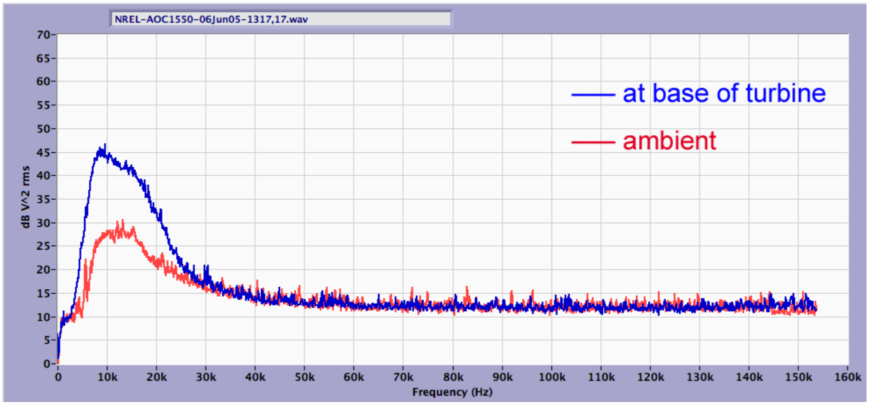

Fig. 2. Relative power spectra of ambient sound and sound generated by the AOC1550 wind turbine at the National Renewable Energy Laboratory, Golden, CO.

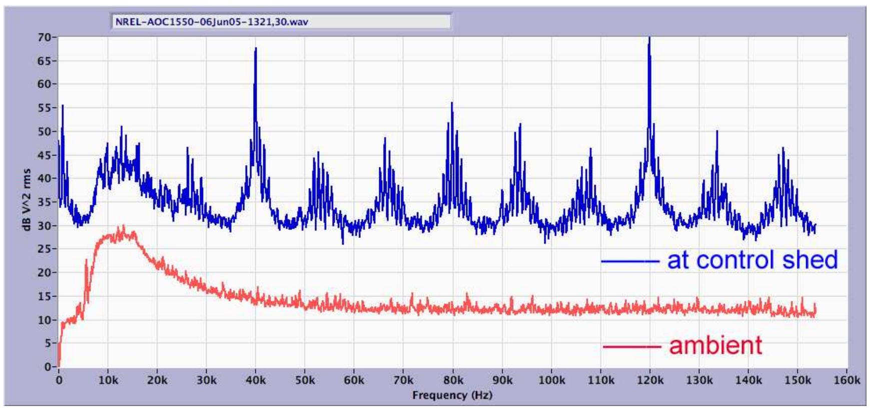

Fig. 3. Relative power spectra of ambient sound and sound recorded at the door of the control shed of the AOC1550 wind turbine at the National Renewable Energy Laboratory, Golden, CO. The relative power in this spectral display is out of scale because the intensity of the sound was sufficient to overload the detector during the recording.

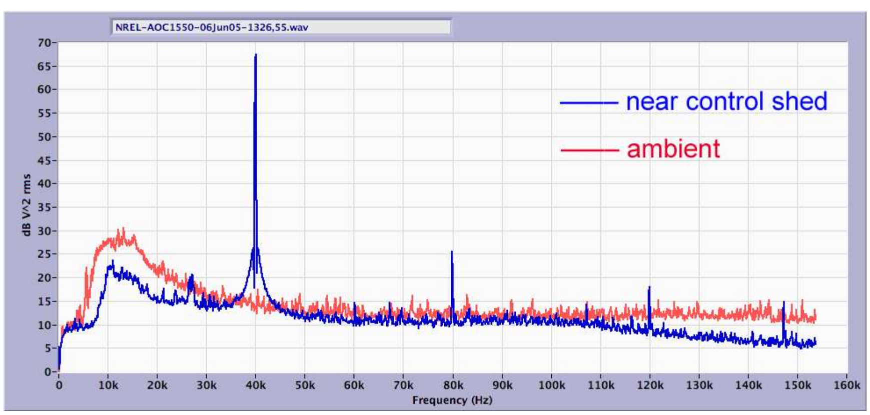

Fig. 4. Relative power spectra of ambient sound and sound recorded approximately 10 m form the door of the control shed of the AOC1550 wind turbine at the National Renewable Energy Laboratory, Golden, CO. The spikes in power at specific frequencies are more accurately represented in this power spectrum compared to Fig. 3.

Rock River, WY

The Mitsubishi 1 MW wind turbine at the Rock River wind facility, Laramie, WY emitted only minor (5 dB) sound emissions above ambient (Fig. 5). The rotating blades of this turbine generated no detectable ultrasound above 30 kHz. There was minor ultrasound generated from 20–30 kHz that exceeded ambient levels.

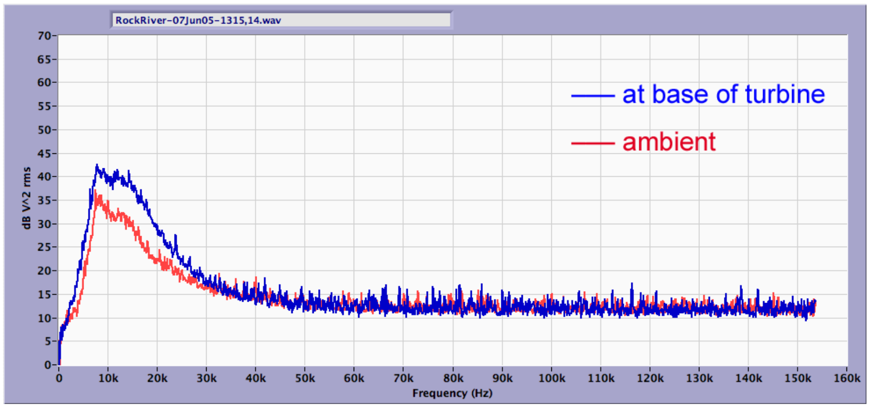

Fig. 5. Relative power spectra of ambient sound and sound generated by the Mitsubishi 1 MW wind turbine at the Rock River Wind Facility, Laramie, WY.

Medicine Bow, WY

The Vestas 660 wind turbines at Medicine Bow, WY emitted whistling sounds audible by ear as the rotors passed overhead in winds in the range of 48–65 kmph. However, essentially all sound was emitted at audible frequencies, i.e., 20 kHz and below (Fig. 6). Sound energy peaked at 15 dB above ambient in a non-uniform frequency distribution that accounted for the whistling sounds heard (Figs. 7 and 8). Despite the audible whistling, the rotating blades of this turbine generated no substantial ultrasound above 30 kHz, with only minor ultrasound generated from 20–30 kHz that exceeded ambient levels.

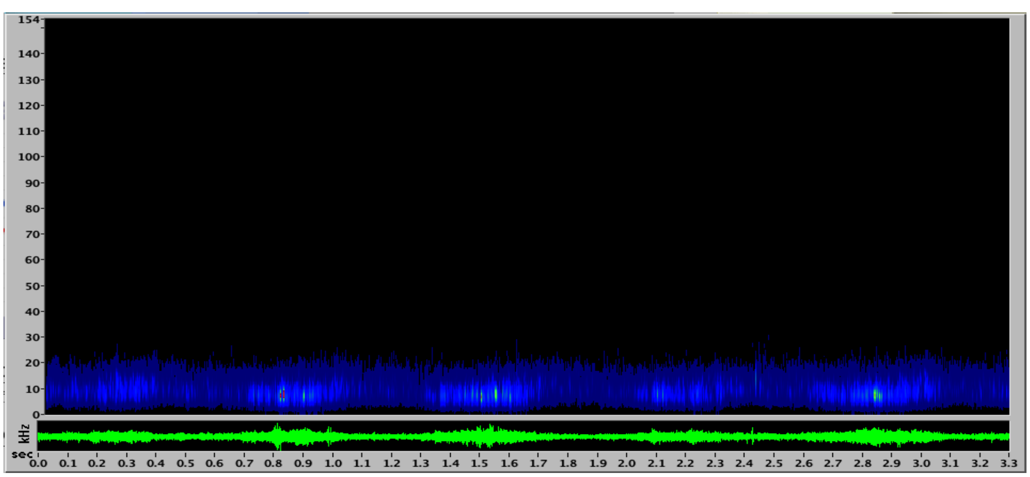

Fig. 6. Sonogram of sound recorded at base of tower below turning rotors of a Vestas 660 wind turbine at Medicine Bow, WY. The sound pulses from five rotor passes are visible in this 3.3 second sonogram. Essentially all the sound energy is in the audible range, i.e., 20 kHz and below.

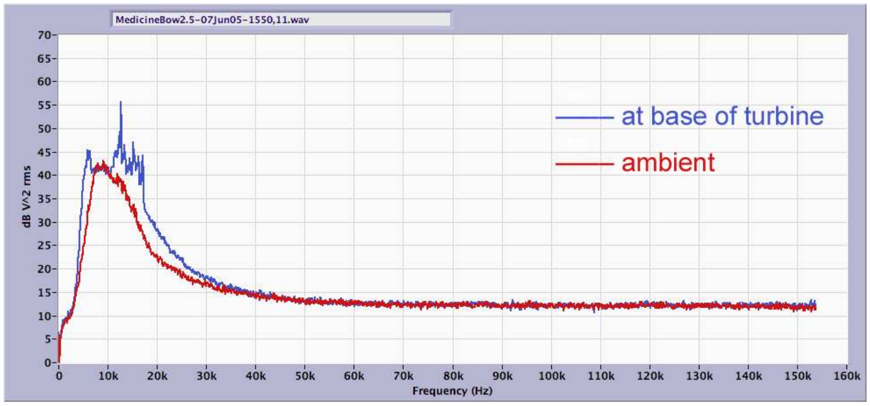

Fig. 7. Relative power spectra of ambient sound and sound generated by the Vestas 660 wind turbine at Medicine Bow, WY.

The control electronics of the Vestas 660 did generate substantial ultrasound, as much as 20 dB above ambient 5 m from its source (Figs. 8 and 9). The frequency distribution of the power in these emissions was broadband, displaying elevated sound energy across the measured ultrasound spectrum (Fig. 8). The sound energy generated by the control electronics was pronounced but localized to its source at the base of the turbine (Fig. 9).

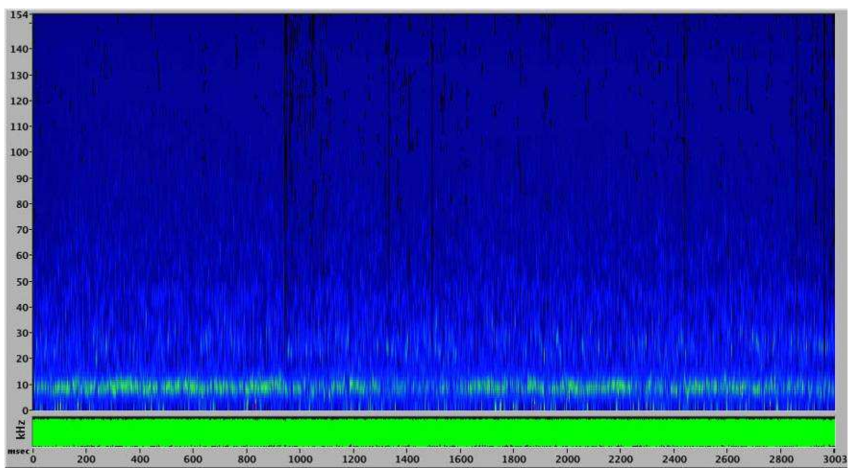

Fig. 8. Sonogram of 3 seconds of sound recorded at the louvered access door at the base of a Vestas 660 wind turbine at Medicine Bow, WY. The emitted sound energy was broadband and continuous across audible and ultrasonic frequencies.

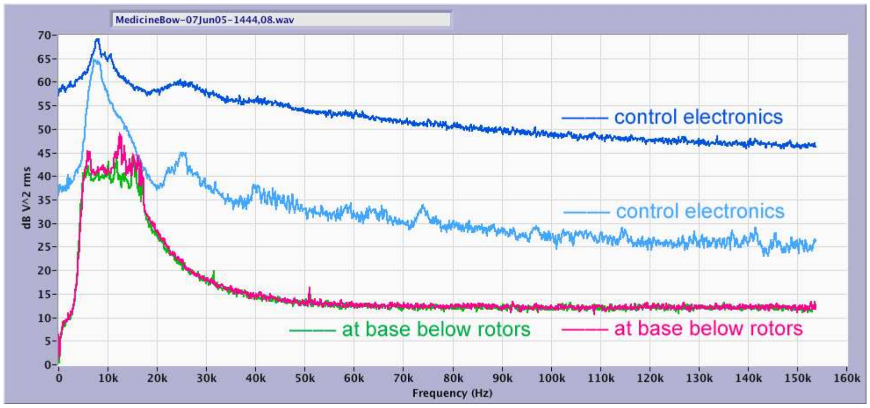

Fig. 9. Relative power spectra of sound emitted from control electronics, ambient sound, and sound generated by the Vestas 660 wind turbine at Medicine Bow, WY. The uppermost spectrum was processed from a recording made directly through the louvered access door at the base of the turbine, the lower electronics spectrum was processed from a recording made 5 m in front of the access door.

A single, prototype Clipper 2.5 MW wind turbine located at Medicine Bow, WY was measured and emitted only minor audible sound energy above ambient with peaks of 10 dB above ambient during winds in the range of 48–65 kmph (Fig. 10). The rotating blades of this turbine generated diminishing levels of ultrasound up to about 30 kHz, above which there was no discernable sound energy emitted above ambient levels. The control electronics of this turbine, located outside of the turbine for prototype testing, generated substantial broad spectrum ultrasound (Fig. 10). However, this sound energy was localized to its source at the base of the turbine and undetectable against ambient at the base of the rotors approximately 25 m away. The control electronics and converter will be located inside the tower for the production model, which should eliminate any substantial ultrasound emissions.

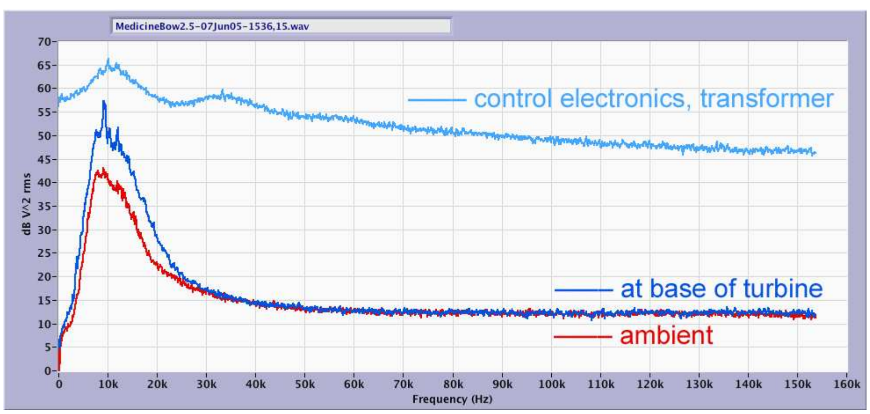

Fig. 10. Relative power spectra of sound emitted from control electronics, ambient sound, and sound generated by the Clipper 2.5 MW wind turbine at Medicine Bow, WY. The electronics spectrum was processed from a recording made 1 m from the transformer and control electronics housing at the base of the turbine.

Kimball, NE

The Neg Micon 1.5 MW wind turbines at Kimball, NE emitted minor (10 dB peak) sound emissions above ambient (Fig. 11). Lower levels of ultrasound were generated from 20–30 kHz that exceeded ambient levels and this diminished to undetectable levels above 30 kHz. The control electronics at the base of this turbine generated sound energy above ambient, but this was only detectable when recorded directly through the louvered access door at the base of the turbine tower (Fig. 12). Sound generated by the electronics was primarily in the audible range and was undetectable above ambient within 10 m from the louvered door at the base of the turbine.

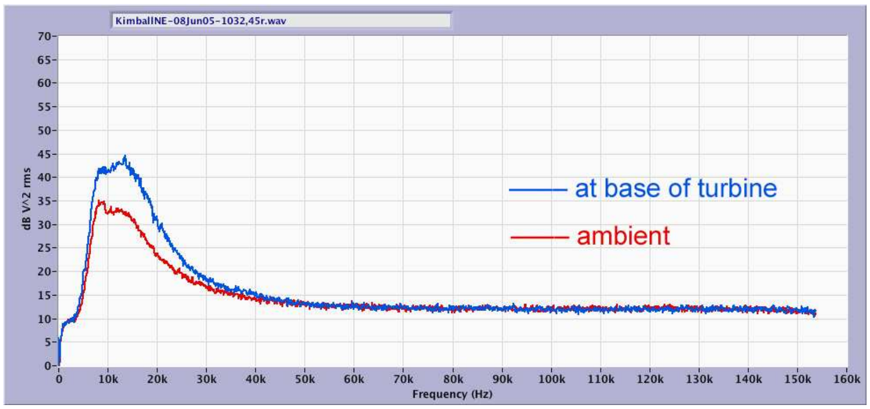

Fig. 11. Relative power spectra of ambient sound and sound generated by the Neg Micon 1.5 MW wind turbines at Kimball, NE.

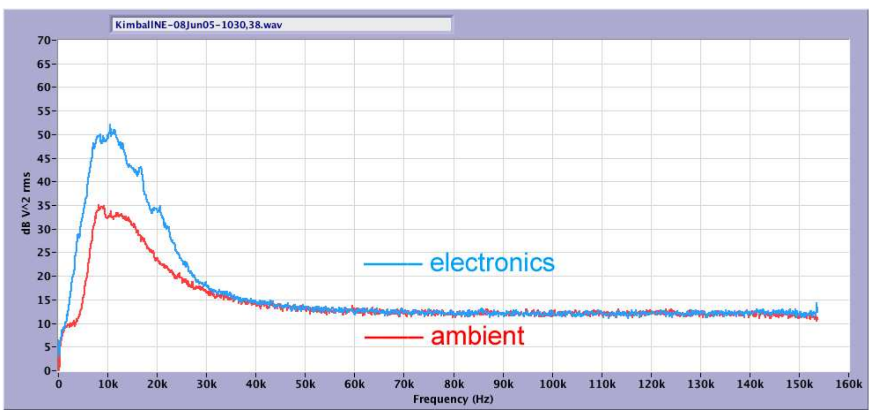

Fig. 12. Relative power spectra of ambient sound control and electronics generated by a Neg Micon 1.5 MW at Kimball, NE. The electronics spectrum was processed from a recording made directly through the louvered access door at the base of the turbine.

Discussion

This preliminary investigation was undertaken to determine whether wind turbines generate ultrasound at levels that could potentially attract bats and draw them into impact range of the moving rotors. If so, this would warrant a more detailed investigation. This preliminary investigation recorded ultrasound from only a limited sample of wind turbines. However, based on this sample, there was no indication that operating wind turbines sampled generate ultrasound at a level that may potentially attract bats to them at a distance. Of particular interest were the Neg Micon 1.5 MW turbines documented to have caused bat mortality at Meyersdale, PA and the Mountaineer facility in WV (Arnett 2005). The NEG Micon 1.5 MW turbines generated only minor sound energy in the low ultrasonic range of 20–30 kHz, and that diminished above 30 kHz to a level indistinguishable from ambient sound levels.

Potential sources of ultrasound from wind turbines include 1) ultrasound generated like a whistle from rotors moving through the air, 2) electronic components, and 3) mechanical components. The transmission and generator components of wind turbines do not turn with rotational speeds at which the generation of ultrasound would be expected. However, loss of lubrication on moving surfaces could occasionally result in ultrasound generation, but the maintenance schedules of the turbines would limit or avoid such occurrences.

Our recordings did find ultrasound generated from the electronics of some units, in particular the AOC1550, Vestas 660 and the Clipper 2.5 MW. However, although noticeable at close proximity to their sources, the power level of these electronic sources was nevertheless insufficient to be detectable above ambient as close as 10 m from them, and not past 20 or 25 m. These “dirty electronic” sources probably do not contribute to attracting bats at a distance to wind turbines, but their presence does implicate electronic equipment as a potential source that should be checked on other types of wind turbines. In particular, because we were unable to record sound near any of the wind turbine nacelles, there remains a potential that ultrasonically dirty electronics in turbine nacelles, even if at similar low power levels, could attract or divert bats that are already in close proximity. The electronics at the base of the Neg Micon 1.5 MW turbines were very clean ultrasonically, i.e., they generated only very low levels of ultrasound, so this potential source may be ruled out as a potential attractant for bats to the sites with those turbines. As noted earlier, the control electronics and converter for the Clipper 2.5 MW turbine will ultimately be located inside the tower for the production model, which should eliminate any substantial ultrasound emissions.

Physical generation of ultrasound from rotors moving through the air would require very small cavities capable of establishing a resonating air column or small defects that generate turbulence. The careful attention to aerodynamic profile and smoothness of the rotors essential for efficient power generation obviates these effects. The spectral sound profiles recorded from the moving rotors largely reflects a simple augmentation of the ambient sound spectral profiles, which rise above a noiseless state from the sound of wind moving through the environment. That is, the wind turbines are set in an already wind-generated noisy environment where the sounds are generated from turbulent airflow over the ground, rocks, vegetation, etc. The profile of sound generated by the wind turbines is similar to the profile of sound that would be generated by wind blowing through a tree, for example; and it could be hypothesized that this sound profile would not create any sort of novel signal that might elicit curiosity to a bat, with the possible exception of the unnatural rhythmicity of these sounds.

Recommendations

Because ultrasound is undetectable to humans, ensuring ultrasound-clean electronics and machinery is not a routine part of their design. Where bat mortalities from strikes with wind turbines occur, the presence of potential ultrasound as a contributing attractant should be undertaken as per this investigation, particularly if the equipment is different than that investigated here. The generation of ultrasound from electronic equipment suggests that at least a spot check of sound levels near wind turbine nacelles may be warranted.

References cited

Ahlen, I. (2003) Wind turbines and bats—a pilot study. Final Report Dnr 5210P-2002- 00473, P-nr P20272-1, Swedish National Energy Commission, Eskilstuna, Sweden (English translation by I. Ahlen, 5 March 2004).

Arnett, E.B., technical editor. (2005) Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA.

Kunz, T.H. (2004) Wind Power: Bats and Wind Turbines**.** *In* S. S. Schwartz, editor. Wind Energy and Birds/Bats: Understanding and Resolving Bird and Bat Impacts. Proceedings of a workshop in Washington, D.C., May 17-18, 2004. RESOLVE, Washington, D.C.

Dr. Joe Szewczak from Humboldt State University records ultrasound from a wind turbine at the National Renewable Energy Laboratory in Golden Colorado (photo by Ed Arnett, BCI).

Dr. Joe Szewczak (kneeling) explains the recording of ultrasound from turbines to Greg Johnson (Western Ecosystems Technology; left) and John Goodell, city administrator from Kimball, Nebraska (photo by Ed Arnett, BCI).