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Effects of Acoustic Deterrents on Foraging Bats

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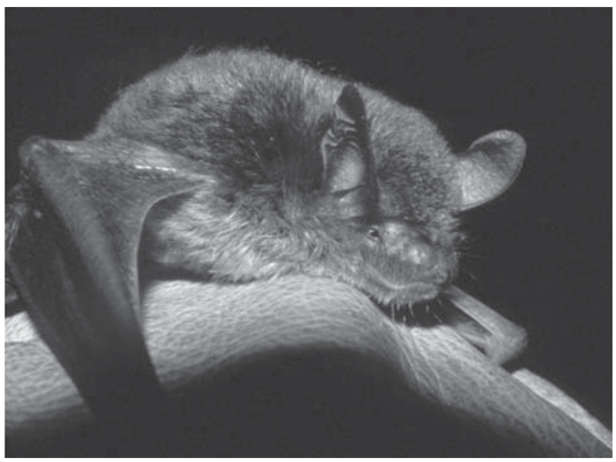

Abstract

Significant bat mortality events associated with wind energy expansion, particularly in the Appalachians, have highlighted the need for development of possible mitigation practices to reduce or prevent strike mortality. Other than increasing turbine cut-in speed, acoustic deterrents probably hold the greatest promise for reducing bat mortality. However, acoustic deterrent effectiveness and practicality has not been experimentally examined and is limited to site-specific case studies. Accordingly, we used a crossover experimental design with prior control period to show that bat activity was reduced 17.1 percent by the deployment of ultrasonic deterrents placed around gauged watershed weir ponds on the Fernow Experimental Forest in West Virginia. We caution that while our results should not be extrapolated to the scope of a typical wind energy production facility, the results warrant further research on the use of acoustic deterrents to reduce bat fatalities.

KEY WORDS: acoustic, Anabat, bats, Fernow Experimental Forest, West Virginia, wind energy

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Cover Photos

Top, northern long-eared myotis bat (*Myotis septentrionalis*), photo used with permission by Tim Carter, Ball State University; center, Anabat SD2 bat detector, photo by Jane Rodrigue, U.S. Forest Service; bottom, weir pond at the Fernow Experimental Forest, photo by Mary Beth Adams, U.S. Forest Service.

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INTRODUCTION

Over the past decade, wind energy production capacity in the United States has increased by an order of magnitude. Wind energy potential is high throughout much of the Appalachians, and several production facilities are located along or near the Allegheny Front in West Virginia and Pennsylvania (Wiser and Bolinger 2011). Unfortunately, many of these sites have experienced unprecedented levels of bat mortality (Arnett et al. 2008). Several hypotheses have been forwarded regarding causes of bat mortality, such as an innate attraction to tall objects, an attraction to high insect concentrations around wind turbines, and attractive acoustical noise (Kunz et al. 2007). Mortalities are mostly comprised of long-distance migratory species (e.g., eastern red bat, *Lasiurus borealis*), and occur from July through September during the late summer and autumn migration periods (Arnett et al. 2008). Recent research has examined several of these hypotheses in an attempt to understand causes of bat mortality at wind energy facilities (Cryan and Barclay 2009). As a result, there have been many bat mortality mitigation measures proposed, including changing wind turbine siting criteria to avoid linear landscape features (Baerwald and Barclay 2009), increasing wind turbine cut-in speeds (minimum wind speeds at which wind turbines generate energy; Baerwald et al. 2009), and placing acoustic deterrents on wind turbines (Szewczak and Arnett 2007).

Though some *ex situ* studies have shown evidence that acoustic deterrents are effective (Schaub et al. 2008), far fewer have concluded this *in situ* (e.g., Szewczak and Arnett 2007). Research indicates that bats avoid ambient noise when foraging, regardless of setting. This characteristic of bats may prove beneficial in mitigating bat mortality at wind energy facilities. Acoustic deterrents emitting ultrasonic signals (12.5-112.5 kHz) in the hearing range of bats have been shown to affect bat foraging activity (Spanjer 2006), presumably through interference in prey detection (Schaub et al. 2008) and flight orientation (Mackey and Barclay 1989). Accordingly, we experimentally determined effects of acoustic deterrents on bat activity at water sources regularly used by bats. We hypothesized that bat activity would be reduced at water sources when acoustic deterrents were operating.

SITE DESCRIPTION

We conducted our research at the Fernow Experimental Forest (FEF) in Tucker County, WV (39°00' N, 79°67' W). The FEF is a 1,900-ha experimental forest managed by the U.S. Forest Service, Northern Research Station, and is located in the unglaciated Allegheny Mountains subsection of the Appalachian Plateau Physiographic Province (Kochenderfer et al. 2007). Elevations range from 530 to 1,100 m. Mean annual precipitation at FEF is 145.8 cm, ranging from 9.7 cm in October to 14.4 cm in June. Mean annual temperature is 9.2 °C, ranging from -18.0 °C in January to 20.6 °C in July (Kochenderfer 2006). Vegetation at the FEF is a mosaic of second- and third-growth mixed-mesophytic and northern hardwood forest. The area has been managed by even-aged (patch clearcut) and uneven-aged (single-tree selection) silviculture since the mid-20th century, or has been left undisturbed following initial harvesting from 1903 to 1911 (Schuler and Fajvan 1999). Approximately 5.5 km of dendritic intermittent and permanent streams incise the steep slopes and plateau-like ridgetops (Madarish et al. 2002). Portions of the western watersheds on the FEF have been devoted to forest hydrology research, and several gauged watersheds have small weir ponds (5 m x 5 m) that are used as water sources and foraging habitat by bats (Ford et al. 2005).

From spring through autumn, the bat community at FEF is comprised of northern long-eared myotis (*Myotis septentrionalis*), little brown myotis (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), tri-colored bats (*Perimyotis subflavus*), eastern red bats, silver-haired bats (*Lasionycteris noctivagans*), and hoary bats (*Lasiurus cinereus*) (Owen et al. 2004, Ford et al. 2005). A small number of endangered Indiana myotis (*Myotis sodalis*) and Virginia big-eared bats (*Corynorhinus townsendii virginianus*), primarily males that hibernate in Big Springs Cave in the central portion of the FEF also remain in the area during summer (Ford et al. 2002).

METHODS

In July 2009, we placed Anabat II (Titley Electronics, Ballina, Australia) broadband, frequency-division bat detectors at four weir ponds in the FEF. Potentially existing within home ranges of bats, the four weir ponds we studied were >100 m apart. At each site, we passively monitored for bat echolocation passes consisting of a series of search-phase or foraging echolocation pulses between 20-80 kHz (Murray et al. 2001). We calibrated each bat detector to 30 m standard detection distance and positioned detectors on weir dams with the microphones angled ~15° from horizontal over the weir ponds. Bat detectors were programmed to monitor from 1 hour prior to sunset to 1 hour after sunrise. Echolocation passes were recorded to Anabat CompactFlash storage Zero-Crossing Analysis Interface Modules (ZCAIM) and downloaded to a computer for analysis using Analook 4.8p software (Corben 2001). After filtering out extraneous noise, we used number of bat passes recorded as an index of bat activity. A bat pass was defined as a series of echolocation pulses or calls emitted by bats (Broders 2003). We did not attempt to identify the species of bat emitting each echolocation pass. Because bat activity can be influenced by nightly temperatures (Anthony et al. 1981), we recorded nightly minimum and daily maximum temperatures (°C) at each weir pond with StowAway® Tidbit® (Onset Computer Corp., Pocasset, MA) data loggers that recorded ambient temperature every minute.

We monitored the four weir ponds simultaneously for four consecutive nights (Period 1: 13-16 July) to establish baseline bat activity levels. Using a crossover experimental design, we then deployed ultrasonic pest deterrents (Model EX900-A, Black and Decker, New Britain, CT) at two randomly chosen weir ponds for three consecutive nights (Period 2: 18-20 July). Ultrasonic pest deterrents broadcasted a varying 26-74 kHz, 105 dB emission, and operated concurrently with Anabat II bat detectors. We used bat detectors to verify that these ultrasonic deterrents were audible around the entirety of each weir pond. On the following three consecutive nights (Period 3: 21-23 July), we deployed ultrasonic deterrents at the other two weir ponds.

We determined if bat activity levels measured as the number of bat passes per night differed among weir ponds during Period 1. Because number of bat passes per night was count data, we modeled it as negative binomially-distributed data. We then compared bat activity between treatment weir ponds (when ultrasonic deterrents were operating) to non-treatment weir ponds. We determined if nightly minimum temperatures and daily maximum temperatures differed among pools during each Period. All analyses were conducted using the GLIMMIX procedure in SAS (SAS Institute Inc. 2004).

RESULTS

Throughout the study, we recorded 15,861 echolocation passes at the four weir ponds. On several nights, Anabat II bat detectors failed to record at one or two weir ponds. As a result, data are missing from two weir ponds on July 14 and one weir pond each on July 16, July 19, and July 23. Temperature loggers failed to record at one weir pond for the duration of the study.

Baseline data collected during Period 1 indicated the mean number of nightly bat passes (±1 SE) among all weir ponds was 598.9±148.1, and that bat activity did not vary significantly among weir ponds ($F_{3,8}$=1.14, P=0.391). Acoustic deterrents used during Period 2 and 3 negatively affected bat activity (t=12.22, P<0.001). Mean number of nightly bat passes recorded at weir ponds where acoustic deterrents were deployed was significantly lower (285.8±102.4) than at ponds on nights when acoustic deterrents were not deployed (344.7±112.8). Mean nightly temperature and mean daily maximum temperature were similar among weir ponds during all three measurement periods (Table 1).

DISCUSSION

As we hypothesized, our results support the supposition that bat foraging activity is reduced by ultrasonic noise (i.e., acoustic deterrents). Szewczak and Arnett (2007) also observed that ultrasonic noise deterred bats from foraging over water sources, but did not consider effects of weather on bat activity. We documented that weather played no significant role in bat activity reductions. Bats are capable, to some extent, of adapting their echolocation processing to account for ultrasonic noise, such as echolocation calls of conspecifics (Chiu et al. 2009). However, in natural settings, they typically avoid areas of ambient ultrasonic noise, such as at rapidly flowing water (Mackey and Barclay 1989).

Table 1.—Mean nightly minimum and mean daily maximum temperatures (°C) at three weir ponds on the Fernow Experimental Forest, West Virginia, 2009.

Period[a]	Temperature	Mean	SE	*F*	d.f.	*P*
1	Mean nightly minimum	12.1	2.0	0.13	2,6	0.882
	Mean daily maximum	24.4	0.9	0.01	2,6	0.993
2	Mean nightly minimum	12.4	0.5	0.01	1,4	0.923
	Mean daily maximum	19.8	0.7	0.12	1,4	0.746
3	Mean nightly minimum	13.2	0.4	0.02	1,4	0.906
	Mean daily maximum	21.0	0.5	1.22	1,4	0.330

[a]Period 1=July 13-16, 2009; Period 2=July 18-20, 2009; Period 3=July 21-23, 2009.

Considering the general agreement among *in situ* and *ex situ* research indicating bats avoid areas where ultrasonic noise is broadcast either naturally or artificially, there is a compelling argument for conducting field experiments where ultrasonic deterrents are broadcasted at wind energy facilities (Kunz et al. 2007). At a wind energy facility in New York, Horn et al. (2008) documented mixed results regarding the effectiveness of ultrasonic deterrents at preventing bats from approaching wind turbines. However, they cautioned that their ultrasonic deterrents may not have been broadcasting at a sufficient decibel level to affect bats outside the rotor-swept area. Because we experimented at small weir ponds, emissions from our ultrasonic deterrents encompassed entire pools, and thus consistently affected bat activity.

To be effective, emissions from ultrasonic deterrents placed on turbine towers or nacelles need to be at decibel levels sufficient to reach beyond wind turbine blade lengths of ~40 m (Horn et al. 2008). Moreover, emissions need to randomly change in pulse duration and intensity to prevent bat habituation (Spanjer 2006). Ultrasonic deterrents also need to operate continuously, as we found bat activity increased following cessation of treatment. Further research examining the effectiveness of ultrasonic deterrents at reducing bat mortality at wind energy facilities holds promise and is warranted considering the results of our research that corroborate with findings of numerous studies.

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