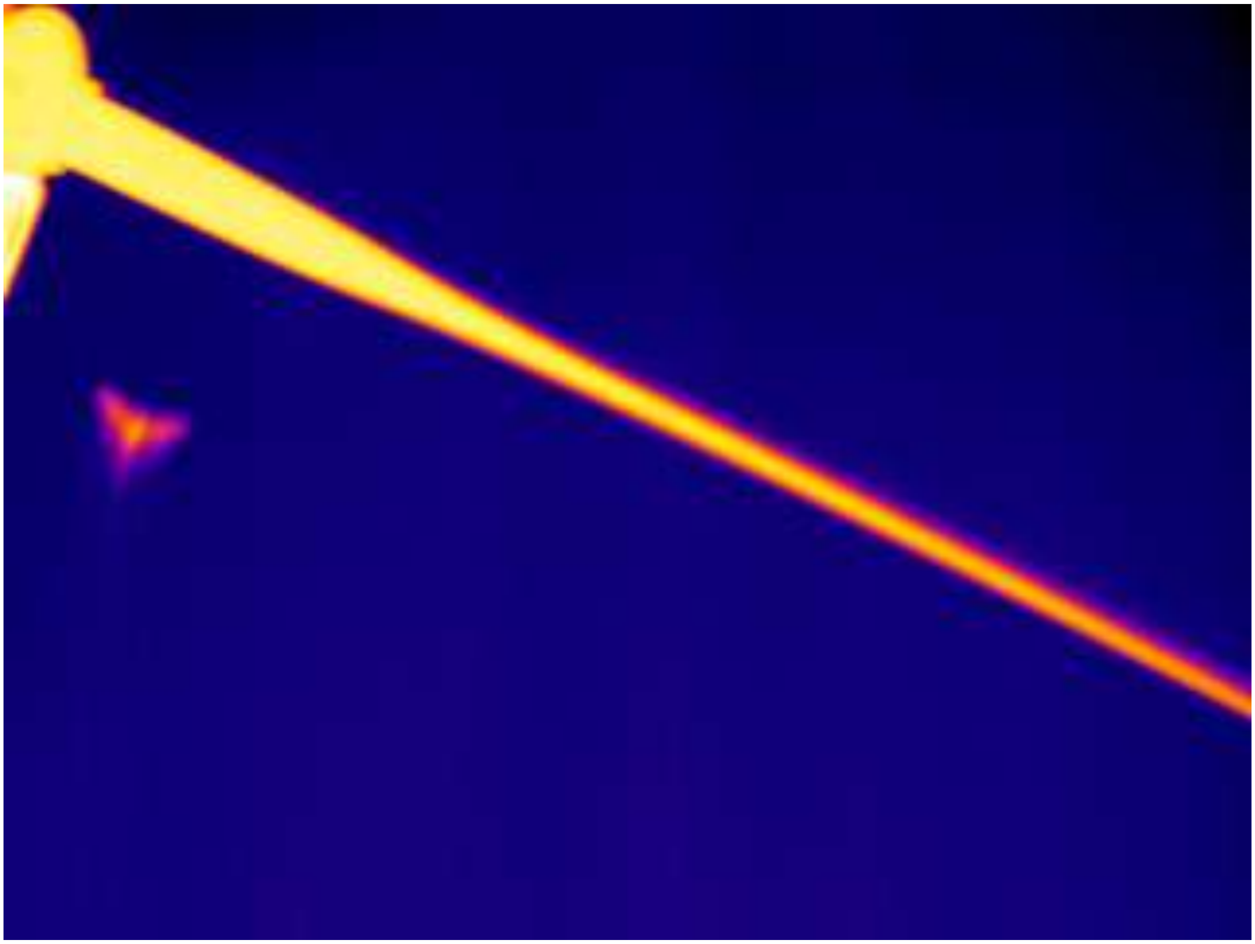
THE BATS and WIND ENERGY COOPERATIVE

Synthesis of Activities (2004–2011), Key Findings and Next Steps



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PURPOSE

This report summarizes the activities of the Bats and Wind Energy Cooperative (BWEC: www.batsandwind.org) from inception (January 2004) to present (July 2011). Here, we synthesize the history, key findings, future deliverables, next steps and financials of the BWEC. Our goal is to provide insight into previous efforts of the BWEC and to set the stage for the upcoming Science Meeting scheduled for January 2012.

BACKGROUND

As concerns about climate change and increasing costs and long-term environmental impacts from the use of fossil fuels have heightened (McLeish 2002), wind has become an increasingly important sector of the energy industry (Pasqualetti et al. 2004) and one of the fastest growing sources of renewable energy. Wind-generated electricity is renewable and generally considered environmentally clean, compared with other energy sources, but is not environmentally neutral. Bat fatalities have been recorded at wind facilities worldwide, including Australia (Hall and Richards 1972), North America (e.g., Johnson 2005, Kunz et al. 2007, Arnett et al. 2008), and Europe (Ahlen 2002, Bach and Rahmel 2004, Dürr and Bach 2004, Brinkman 2006). Small numbers of bats were first recorded in the U.S. at wind energy projects in California during avian fatality searches (e.g., Orloff and Flannery 1992, Thelander and Rugge 2000). However, bat fatalities at wind energy facilities generally received little attention in North America until 2003 when an estimated 1,400–4,000 bats were killed at the Mountaineer Wind Energy Center in West Virginia (Kerns and Kerlinger 2004). Although bat fatalities are widespread, the full extent and impact remain inadequately investigated and poorly understood. Given our current state of knowledge and the projected future development of wind energy facilities in the U.S. (i.e., projected 35 Gigawatts by 2030), the potential for significant cumulative population impacts to bats is an important concern (Kunz et al. 2007).

A leadership meeting was held at BCI headquarters in Austin, Texas to form the Cooperative.

Shortly after the discovery at Mountaineer, the BWEC was formed by Bat Conservation International (BCI), the US Fish and Wildlife Service (USFWS), the American Wind Energy Association (AWEA), and the National Renewable Energy Laboratory of the US Department of Energy (NREL), with the mission to develop solutions to minimize or, where possible, prevent mortality of bats at wind power turbines. The BWEC works cooperatively with diverse stakeholders, including state and federal agencies, private industry, academic institutions, and non-government organizations to secure and administer funding and allocate resources to conduct local, regional, and continent-wide research required to address issues and develop solutions surrounding wind energy development and impact to bats.

BWEC Science Meetings

1st BWEC Science Meeting (February 2004; Juno Beach, Florida)

In February, 2004, the inaugural Bats and Wind Power Generation Technical Workshop, sponsored by BCI, USFWS, AWEA and NREL was held in Juno Beach, Florida. The purpose of this workshop was to 1) identify what is currently known and where information needs exist; 2) discuss available methods and technologies; 3) review current knowledge of relevant bat behavior and ecology, and 4) develop priorities for BWEC research efforts. Several of the world's leading bat scientists and experts from relevant fields, wind industry, and federal and state agencies gathered to share information and discuss what is needed to understand and resolve issues involving bat mortality at wind turbines. A list of priorities and suggestions was developed for conducting research essential to: 1) understand potential causes of bat mortality at turbines; 2) correlate turbine characteristics, habitat, and weather patterns with bat mortality; and 3) minimize or, where possible, prevent bat kills at turbines.

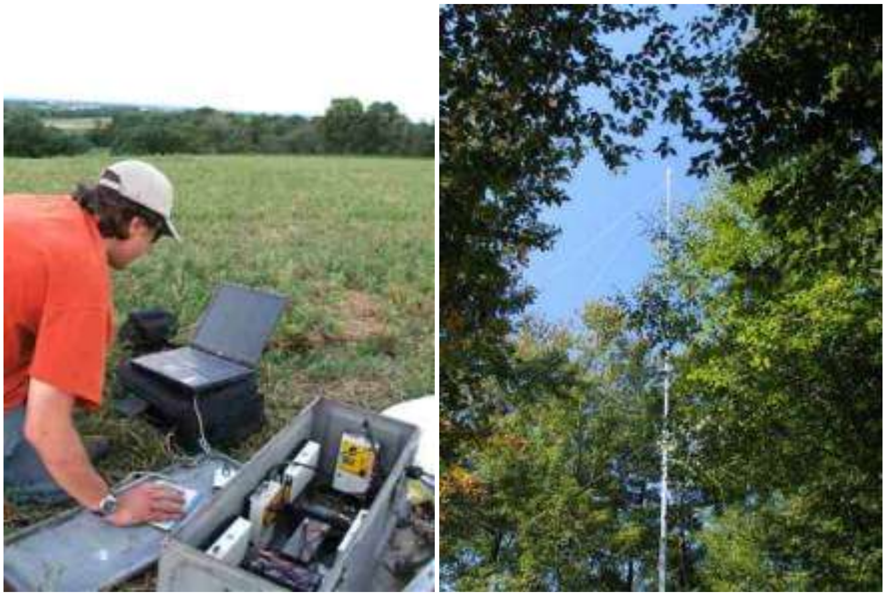
2nd BWEC Science Meeting (January 2008; Austin, Texas)

The BWEC completed four years of field research in fall 2007 and held a second technical workshop in Austin, Texas, in January, 2008. Findings from BWEC-sponsored studies were presented and new priorities set forth. Several presentations were delivered and break-out sessions helped to develop top priorities for the next few years of BWEC research, including (in order of priority) : 1) operational mitigation studies and deterrent research; 2) pre-construction risk assessment methods; 3) post-construction monitoring and risk assessment; and 4) evaluation of population parameters and modeling. The BWEC research agenda since this meeting has primarily focused the first three topics.

BWEC RESEARCH

Pre-construction Risk Assessment Methods

Pre-construction surveys at wind facilities commonly employ acoustic detectors, placed at different heights above ground level (agl) to assess local bat species presence and activity. Understanding bat activity levels prior to construction of wind facilities may assist in identifying habitats and features that may pose high risk of fatality and aid with decision-making, including specific placement of turbines. However, using this information to predict bat fatality, and thus risk, at a site or region has proved challenging. BWEC scientists have contributed to and conducted several intensive studies to 1) determine levels and patterns of activity of different phonic groups of bats using proposed wind facilities prior to construction, and 2) correlate bat activity with weather and other environmental variables. These results will be combined with other studies to assess if indices of pre-construction bat activity can be used to predict post-construction bat fatalities.



Setting up Anabat acoustic detectors (left). A portable tower (right) with a detector microphone attached at 22 m extending above the canopy.

Arnett, E. B., J. P. Hayes, and M. M. P. Huso. 2006. Patterns of pre-construction bat activity at a proposed wind facility in south-central Pennsylvania. An annual report.

The BWEC initiated a 5-year study in mid-summer 2005 to determine patterns of bat activity and evaluate the use of acoustic monitoring to predict fatality of bats at a proposed wind facility in south-central Pennsylvania. Using Anabat II acoustic detectors positioned at 1.5, 22, and 44 m (agl) on 5 meteorological towers, and at 1.5 and 22 m (agl) on 10 portable towers, we recorded a total of 9,162 bat passes. Bat activity was highest from mid-August through mid-September. Activity rates of high-frequency bats (≥35 kHz, e.g., *Myotis*) was estimated to be 9–59% greater than that of low-frequency bats (<35 kHz, e.g., *Eptesicus fuscus*) at 1.5 m. This trend was reversed at 44 m where it was estimated that activity rates of low-frequency bats was 17–210% greater than that of high-frequency bats. Total bat activity increased with increasing temperature up to about 19–21 °C, after which activity began to decline. For every 1 °C increase in temperature, bat activity increased 7–13% at 1.5 m, 0–7% at 22 m, but was unaffected by temperature at 44 m. The effect of wind speed was the same for both phonic groups at all heights. For each 1 m/s increase in wind speed, activity rate was estimated to decrease by 11–39%.

Redell, D., E. B. Arnett, J. P. Hayes, and M. M. P. Huso. 2006. Patterns of pre-construction bat activity determined using acoustic monitoring at a proposed wind facility in south-central Wisconsin. A final report.

BWEC scientists partnered with Dave Redell and the Wisconsin Department of Natural Resources to conduct an effort similar to the Pennsylvania study to determine patterns of bat activity and evaluate the use of acoustic monitoring to predict fatality of bats at a proposed wind energy facility in south-central Wisconsin. Specifically, the goal of this study was to provide information to minimize mortality of bats migrating to Neda Mine and through the area. Using Anabat II acoustic detectors positioned at 2, 22, and 48 m (agl) on 3 meteorological towers, and at 2 and 22 m on 5 rotating mobile towers, we recorded 26,495 bat passes. Bat activity was highest in August with secondary peaks in late July and September. Activity of high-frequency bats ws estimated to be 3.2–5.5 times greater at 2 m than at 22 m, and 3.8–7 times greater at 2 m than at 48 m. There was no detectable difference in activity at any height for the low-frequency phonic group. Activity of *Myotis* spp at 2 m decreased between 6 and 28% for every kilometer increase in distance from the Neda Mine. Temperature and wind speed affected bat activity rates at our site, but the effect of temperature differed for the two phonic groups. For each 1 °C increase in temperature, the activity rate of high-frequency and low frequency bats was estimated to increase by 3–9% and 7–13%, respectively. For every 1 m/s increase in wind speed, the activity rate of bats was estimated to decrease by 4–13%.

Arnett, E. B., M. M. P. Huso, D. S. Reynolds, and M. R. Schirmacher. 2007. Patterns of pre-construction bat activity at a proposed wind facility in northwest Massachusetts. An annual report.

The BWEC initiated a 2-year pre-construction study in mid-summer 2006 to determine patterns of bat activity and evaluate the use of acoustic monitoring to predict mortality of bats at a proposed wind energy facility in northwest Massachusetts. Using Anabat II acoustic detectors positioned at 10, 31, and 39 m (agl) on 5 meteorological towers, we recorded 4,816 bat passes. Arnett et al. estimated that activity rates for high-frequency bats were 1.5–4.0 times greater than those of low-frequency bats at 10 m. This trend was reversed at higher altitudes, where it was estimated that activity rates for low-frequency bats were 5.8–22.9 and 11.2–38.8 times greater than those of high-frequency bats at 31 and 39 m, respectively. Bat activity was related to temperature, but the effect differed by phonic group. For every 1 °C increase in temperature, activity increased 14–57% and 5–34% for high-frequency and low-frequency bats, respectively. Bat activity increased slightly with increasing wind speed, but then decreased at higher wind speeds. In general, when temperatures were warm (≥20 °C) and wind speeds were moderate (approximately 8 m/s), the predicted number of passes on any night was low, except for high-frequency bats.

Kunz, T. H., E. B. Arnett, B. M. Cooper, W. P. Erickson, R. P. Larkin, T. Mabee, M. L. Morrison, M. D. Strickland, and J. M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife management 71:2449–2486.

The purpose of this document is to provide guidance on methods and metrics for investigating nocturnally active birds and bats in relation to utility-scale wind-energy development. The objectives of such studies are to 1) assess potential impacts on resident and migratory species, 2) quantify fatality rates on resident and migratory populations, 3) determine the causes of bird and bat fatalities, and 4) develop, assess, and implement methods for reducing risks to bird and bat populations and their habitats. Methods, limitations, assumptions, and data interpretation are described in this document. Moreover, suggestions to improve studies and best practices for research are presented.

Weller, T, J. 2007. Pre-construction sampling regimes for assessing patterns of bat activity at a wind energy development in southern California.

The BWEC contributed financial support and expertise to design and implementation of all phases of this study. This project aimed at assessing patterns of bat activity at a wind energy development in North Palm Springs, California. Anabat II acoustic detectors were attached at 2, 22, and 52 m agl on 4 meteorological towers, and at 2, and 22 m on 12 portable towers. Bat activity was relatively low during the study period, with a total of 61 detections. Low-frequency bats were recorded more frequently at 52 m than at 2 or 22 m. Conversely, high frequency bats were infrequently recorded at 52 m. Wind speed and temperature were important predictors of observed bat activity with highest periods of activity on nights with the highest temperatures and lowest wind speeds.

Pulley system for deploying acoustic detector microphones in "bat hats."

Boom truck used to mount pulley system

A mounted pulley system and bat hat at 22 m high.

Hein, C. D., E. B. Arnett, M. R. Schirmacher, M. M. P. Huso, and D. S. Reynolds. 2011. Patterns of pre-construction bat activity at the proposed Hoosac Wind Energy Project, Massachusetts, 2006-2007. A final report.

The BWEC completed its 2-year preconstruction acoustic monitoring study at a proposed wind facility in northwest Massachusetts. This report builds on the Arnett et al. (2006) study (see above). Using Anabat II acoustic detectors positioned at 10, 31, and 39 m (agl) on 5 meteorological towers, we recorded 4,816, and 9,802 bat passes in 2006 and 2007, respectively. Bat activity was highest between mid-July and mid-August for all phonic groups. High-frequency bats were detected more often at 10 m and low-frequency bats more often at 31 and 39 m. Both the probability of activity and estimated number of calls from each phonic group increased by as much as 39% for every 1 °C increase in temperature. While wind speed was important, it never explained more than an additional 3.6% of the variation in activity.

Key Findings from Pre-construction Acoustic Monitoring Studies

Although we have yet to identify relationships between pre-construction activity and post-construction fatality, these studies provide insight into the activity patterns of bats. In general, these studies showed consistency in nightly and seasonal flight behaviors of bats, with the highest nightly activity shortly after sunset and peaks in seasonal activity in late summer and early fall. Furthermore, all studies showed a relationship between bat activity and weather conditions, specifically temperature and wind speed. These data have been used to assess the timing and conditions bats may be at most risk to wind development and have assisted in implementing operational mitigation strategies.

Post-construction Monitoring and Risk Assessment

BWEC scientists began efforts to study interactions between bats and wind turbines, and patterns of fatality during late summer and early fall 2004, the time of year during which bat fatalities appear to occur most frequently at wind energy facilities. Previous studies included applying thermal imaging to observe interactions between bats and wind turbines, conducting fatality searches to document bat mortalities at wind turbine site, and performing extensive analyses of fatality data to identify patterns and relationships with weather and other variables.

BCI Founder Dr. Merlin Tuttle and Jessica Kerns inspect bats killed by wind turbines.

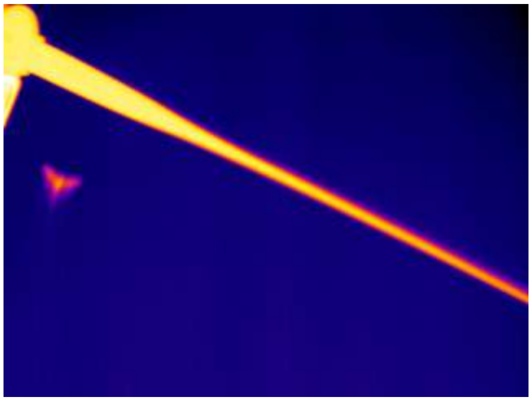
A hoary bat killed by a wind turbine.

Arnett E. B. (editor). 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: An assessment of fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines.

The BWEC investigated relationships between bats and wind turbines at the Mountaineer Wind Energy Center, West Virginia, and the Meyersdale Wind Energy Center, Pennsylvania. A total of 398 and 262 bat fatalities were recovered during searches at Mountaineer and Meyersdale, respectively. Fatalities were distributed across all turbines, except for 1 turbine which was non-operational throughout the study period. Timing of fatalities was highly correlated between the two sites. The majority of bats were killed on low wind nights when power production appeared to be insubstantial, but turbine blades were still moving, often times at or close to full operational speed (17 rpm). The estimated fatality at Mountaineer was 38 bats/turbine (90% CI: 31–45). The total number of bats estimated to have been killed at the 44 turbines during the 6-week period was 1,364–1,980. At Meyersdale, an estimated 25 bats were killed per turbine (90% CI: 20–33), resulting in an estimated total of 400–660 bats killed at 20 turbines during the 6-week study period.

Two additional study components are included in this report, and results can be found in other publications. See Arnett (2006) and Horn et al. (2008) for summaries of the use of dogs to recover bat fatalities and on the use of thermal imaging to observe bat flight behavior at wind turbines, respectively.

Brian Cooper with ABR, Inc. sets up marine radar to track birds and bats at Mountaineer in West Virginia.



Thermal imaging revealed for the first time interactions between bats and wind turbines.

Arnett, E. B. 2006. A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. Wildlife Society Bulletin 34:1440–1445.

Arnett assessed the ability of dog-handler teams to recover dead bats during fatality searches at the Mountaineer and Meyersdale Wind Energy Centers in West Virginia and Pennsylvania, respectively, to determine fatality rates for birds and bats. Dogs found 71% of bats used during searcher-efficiency trials at Mountaineer and 81% of those at Meyersdale, compared to 42% and 14% for human searchers, respectively. Dogs and humans found high proportions of trial carcasses near the turbine, usually on open ground. However, humans found fewer carcasses as vegetation height and density increased, while dog-handler teams searcher efficiency remained high.

BWEC project coordinator Ed Arnett observes a Tri-colored bat killed by a wind turbine that was found by his chocolate Labrador retriever Sage.

Arnett, E. B., W. K. Brown, W. P. Erickson, J. K. Fiedler, B. R. Hamilton, T. H. Henry, A. Jain, G. D. Johnson, J. Kerns, R. R. Koford, C. P. Nicholson, T. J. O'Connell, M. D. Piorkowski, and R. D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72:61–78.

Arnett et al. synthesized available information on patterns of bat fatalities from a review of 21 post-construction fatality studies conducted at 19 facilities in 5 US regions and 1 Canadian province. Dominance of migratory, tree-roosting lasiurine species killed by turbines was consistent among studies. Bat fatalities, although highly variable, consistently peaked in late summer and fall, coinciding with migration. However, pregnant female Brazilian free-tailed bats were vulnerable in May and June at a facility in Oklahoma and female silver-haired bat fatalities were reported in spring in Tennessee and Alberta, Canada. Most fatalities were distributed randomly across turbines at a site. No studies found differences in bat fatalities between turbines equipped with FAA lighting and unlit turbines. All studies addressing relationships between bat fatalities and weather patterns found that most bats were killed on nights with low wind speeds (<6 m/s), and that fatalities increased immediately before and after passage of storm fronts.

Horn, J. W., E. B. Arnett, and T. H. Kunz. 2008a. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72:123–132.

Horn et al. used thermal infrared cameras to assess the flight behavior of bats at wind turbines at the Mountaineer Wind Energy Center, WV. On 10 nights, a total of 2,398 observations were made using thermal imaging cameras, of which 41% (n = 998) were identified as bats. Nightly bat passes observed at a single turbine ranged from 9–291 passes. Most bat activity was observed within 2 hr past sunset. Thermal images indicated that bats 1) approached both rotating and non-rotating blades, 2) followed or were trapped in blade tip vortices, 3) investigated the various parts of the turbine with repeated fly bys, and 4) were struck directly be rotating blades. Observed collisions (n = 4) were between bats and fast-moving (17 rpm) turbine blades.

Arnett, E. B., M. R. Schirmacher, M. M. P. Huso, and J. P. Hayes. 2009a. Patterns of bat fatality at the Casselman Wind Project in south-central Pennsylvania: 2008 Annual Report.

The BWEC investigated the patterns of bat fatality at the Casselman Wind Project, PA in 2008. Daily searches were conducted at 10 of 23 turbines between 19 April and 15 November. Arnett et al. found 148 carcasses of 6 species of bats. Hoary bats, silver-haired bats, and eastern red bats were killed most frequently, representing 75% of estimated fatalities, and tricolored and little brown bats represented 11 and 10% of estimated fatalities, respectively. One hundred twenty-four (84%) of all bat carcasses were found between 15 July and 15 October, with no carcasses found after 24 October. The estimated number of bat fatalities per turbine was 32.3 (95% CI: 20.8–51.4), 1.1 (95% CI: 0.5–2.3), and 18.9 (95% CI: 15.3–22.9) for the Huso, Naïve, and modified estimators, respectively. Mean fatalities per turbine from the forested ridge portion of the project was 32.3 (n = 7 turbines; 95% CI: 22.4–43.7), while mean fatalities per turbine from the strip mine ridge was 32.5 (n = 3; 95% CI: 24.5–42.5), indicating no difference in fatalities between these two ridges and habitat conditions.

Key Findings from post-construction monitoring studies

The timing and weather conditions of peak bat fatalities are similar to activity patterns recorded during pre-construction acoustic monitoring studies. Bat fatalities tend to be highest in late summer and early fall, and are typically highest on warm nights with lower wind speeds. Although we have yet to determine whether pre-construction acoustic surveys can be used to predict overall risk of a site, these data can assist in determining the flight behavior of bats, which may be useful in predicting the timing and under what weather conditions fatalities might occur. Our studies provided insight into bat migratory patterns and flight behaviors. We found that fatalities are predominately comprised of migratory tree-roosting bats and that fatalities between two study sites, located approximately 150 km away from each other, appear correlated, indicating migration occurs across a broad landscape, or regional scale. Thermal imaging revealed bats actively investigating both moving and non-moving blades. These data suggest bats (or at least some species of bats) may be attracted to wind turbines.

Operational Mitigation Studies & Deterrent Research

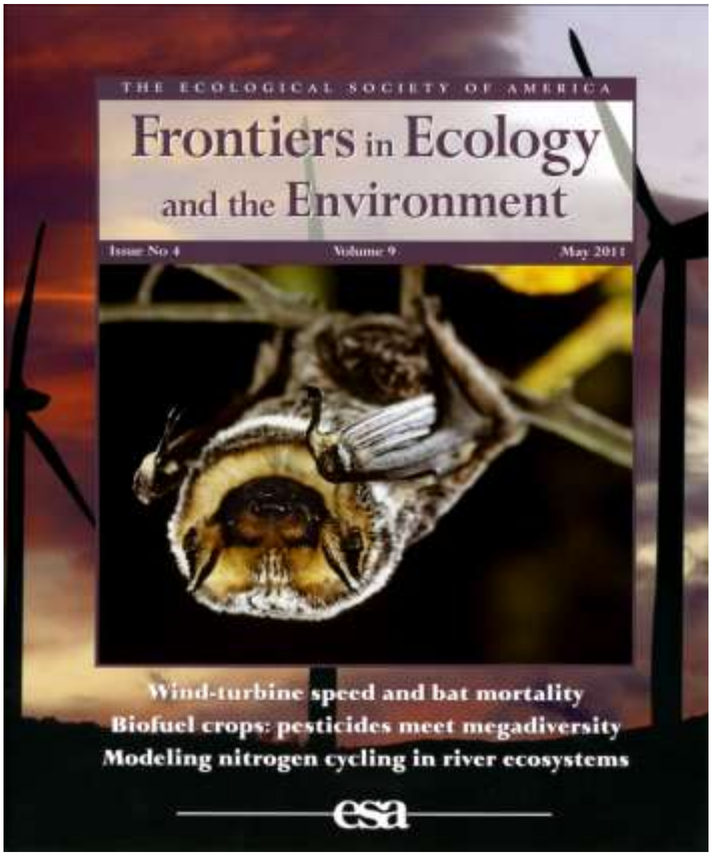
Changing Turbine Cut-in Speed

Patterns of bat fatality, relationships between weather and turbine variables, and observations with thermal imaging all corroborate and suggest bat fatalities primarily occur on low wind nights, but mostly when turbine blades are rotating at or near their maximum speed. Seasonal low wind shutdowns during predictable nights or periods of high bat kills could reduce fatalities considerably, potentially with modest reduction in power production and associated economic impact on project operations. Two study reports and a journal publication in Frontiers in Ecology and the Environment document the findings of the first U.S.-based study investigating the ecological and economic efficacy of changing turbine cut-in speed to reduce bat fatalities at wind energy facilities.

Arnett, E. B., M. R. Schirmacher, M. M. P. Huso, and J. P. Hayes. 2009b. Effectiveness of changing wind turbine cut-in speeds to reduce bat fatalities at wind facilities. An annual report.

Arnett, E. B., M. M. P. Huso, J. P. Hayes, and M. R. Schirmacher. 2010. Effectiveness of changing wind turbine cut-in speeds to reduce bat fatalities at wind facilities. A final Report.

Arnett, E. B., M. M. P. Huso, M. R. Schirmacher, and J. P. Hayes. 2011. Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment 9:209–214.



Cover of May issue of *Frontiers in Ecology and the Environment* highlighting Arnett et al. (2011).

The BWEC initiated a 2-year study in July 2008 to test the effectiveness of raising wind turbine cut-in speed – defined as the lowest wind speed at which turbines generate power to the utility system, thereby reducing turbine operation during periods of low wind speeds – to decrease bat mortality at the Casselman Wind Project, Pennsylvania. Twelve of 23 turbines at the study site were randomly selected for the experiment and we employed three treatments at each turbine: 1) fully operational, 2) cut-in speed at 5.0 m/s (C5), and 3) cut-in speed at 6.5 m/s (C6), with four replicates on each night of the experiment.

We found a total of 32 and 39 fresh bat fatalities at the 12 treatment turbines in 2008 and 2009, respectively. There was no difference between the number of fatalities for the C5 and C6 turbines, but strong evidence for a difference between fully operational turbines and those with altered cut-in speeds. Observed bat mortality at fully operational turbines was, on average 5.4 and 3.6 times greater than mortality associated with curtailed (i.e., non-operating) turbines in 2008 and 2009, respectively. Relatively small changes to wind-turbine operations resulted in nightly reductions in bat mortality, ranging from 44 to 93% with marginal annual power loss (≤1% of total annual output).

Deterrent Research

In 2006, BWEC scientists partnered with Dr. Joe Szewczak from Humboldt State University and acoustic and neurological expert Dr. Cindy Moss from the University of Maryland to being testing the efficacy of deterring devices as a possible means of reducing bat fatalities at wind turbines. We hypothesized that the best results will come from high amplitude sonar “jamming” sounds, taking a lesson from moths that emit such noises to deter bats. The goal of these studies was to utilize our knowledge of bat ecology, auditory biology, habitat bioacoustics, and animal behavior to investigate specific behavioral relationships of bats as they relate to the development of mechanisms to alert bats to turbine presence and/or deter them away from turbines.

Arnett, E. B. and J. M. Szewczak. 2006. Ultrasound emissions from wind turbines as a potential attractant to bats: a preliminary investigation.

Arnett and Szewczak performed an evaluation of the ultrasound emissions from a variety of wind turbines to determine whether ultrasound emissions may contribute to attracting bats toward wind turbines. 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. They concluded that ultrasound emissions, as measured from the ground, do not likely play a significant role in attracting bats.

Spanjer, G. R. 2006. Responses of the big brown bat, Eptesicus fuscus, to an acoustic deterrent device in a lab setting.

Spanjer tested the response of bats to a prototype, eight speaker deterrent emitting broadband white noise at frequencies from 12.5 to 112.5 kHz at about 100 dB SPL per speaker at 1 m. The effect of broadcasting ultrasound on bats flying in feeding or non-feeding trails with the acoustic deterrent device placed among four quadrants in a flight chamber was measured. In half the trials, the acoustic deterrent broadcast broadband noise, and in half the trials, the device remained silent. In non-feeding trials, bats

Laboratory setup at the University of Maryland to test effects of ultrasound emission on captive bats.

A pond in eastern Oregon where numerous bats were known to drink and feed; this site was used to field test the deterrent.

landed in the quadrant containing the device significantly less when it was broadcasting broadband noise. In feeding trials, bats never successfully took a tethered mealworm when the device broadcast sound, but captured mealworms near the device in about 1/3 of trials when it was silent. Bats in both feeding and non-feeding trials flew through the quadrant containing the device significantly less when it broadcast noise than when it remained silent.

Szewczak, J. M. and E. B. Arnett. 2006. Preliminary field test results of an acoustic deterrent with the potential to reduce bat fatality from wind turbines

Szewczak and Arnett tested a prototype acoustic deterrent at eight different sites (i.e., ponds) during July and August in California and Oregon. Foraging activity was monitored for two nights at each site to establish baseline activity levels. After observing activity similar to baseline levels on a third night, the deterrent devices were activated. They measured activity in the same way each night by counting “visual passes” of bats entering and leaving the recorded view from a Sony Nightshot video camera equipped with a high intensity infrared lamp. For the same 1-hr period each night the mean baseline activity was 419±153 passes, compared to 238±88 passes with the ultrasound regime active ($P \leq 0.025$). Bats appeared most affected closer to the ultrasound emitter, suggesting that increasing the amplitude of the sound regime may increase the effectiveness and range of this approach.

Szewczak, J. M. and E. B. Arnett 2008. Field test results of a potential acoustic deterrent to reduce bat mortality from wind turbines.

Szewczak and Arnett monitored foraging activity at 6 different ponds during August and September 2007 in Arizona, California, and Oregon for at least two nights to establish baseline activity levels, and then for 5 to 7 days of continuous treatment with ultrasound broadcast. They measured activity by counting visual passes of bats entering and leaving the recorded view from a Sony Nightshot video camera with a field of view illuminated with high intensity infrared lamps. The median activity rate/hour, when the ultrasound was broadcast was estimated to be between 2.5 and 10.4% of the activity rate when no ultrasound was broadcast. Results indicated that ultrasound deterred bats and suggested that bats did not habituate or accommodate to continued broadcast of ultrasound for the duration of the study period, suggesting bats may learn to avoid treated airspace. However, the effective range of the ultrasound broadcast from the device we tested did not extend beyond approximately 12–15 m.

Horn, J., E. B. Arnett, M. Jensen, and T. H. Kunz. 2008. Testing the effectiveness of an experimental acoustic bat deterrent at the Maple Ridge Wind Farm.

Horn et al. tested the first experimental ultrasonic bat deterrents designed for commercial-scale wind turbines at the Maple Ridge Wind Farm, New York. The deterrents emit randomized and continuous ultrasound designed to interfere with normal echolocation in insectivorous bats. Deterrents were mounted on the towers of two treatment turbines and two control turbines with similar landscape characteristics and historic mortality rates and we performed two experiments in succession. For each experiment, we simultaneously observed one treatment and one control turbine nightly for 10 consecutive nights using thermal infrared imaging cameras. We monitored an area within the rotor-swept zone adjacent to the mounted deterrents nightly for 3.6 hours beginning shortly after sunset. Overall, Horn et al. observed 618 occurrences of bats (an estimated 566 bat passes) during 288 hours of video, yielding a rate of 4–46 passes on a given night (1.9 bats/hr). While most bats observed were engaged in normal flight, 2% avoided collisions (n = 12), 3% investigated the turbines (n = 16), and <1% collided with the turbine blades (n = 2). Twenty-eight percent of bats flew within the rotor-swept zone (n = 158). On the first 10-night test, a total of 131 bats were observed at the deterrent-treated turbine versus 244 bats at the control turbine – a statistically significant difference. However, during the second test, there was no significant difference in bat activity between the treatment and control turbines.

Tom McRoberts with Deaton Engineering attaches an acoustic deterrent device to a wind turbine.

Arnett et al. (2011). Evaluating the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind facilities. A final report.

The BWEC implemented a 2-year study to test the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines at the Iberdrola Renewables' Locust Ridge I and II Wind Farms, Pennsylvania. Of 64 turbines available, 10 were fit with deterrent devices on the nacelle; 3 devices were fit to each side of the nacelle and pointed downward into the rotor swept area and two were aimed at a reflector plate to send ultrasonic emissions into the upper part of the rotor swept area (8 devices total for each of the 10 turbines). Each device has 16 speakers and emits a resonance frequency of 50 kHz. We conducted daily searches under these 10 treatment turbines as well as 15 control turbines.

In 2009, a total of 59 bat fatalities were found at the 10 deterrent turbines and 135 at control turbines. The average per-turbine fatality rate at deterrent turbines was significantly less than at control turbines. Arnett et al. estimated an average of 11.6 bats (95%: 9.4–14.1) were killed per turbine at deterrent turbines, compared to 18.4 bats (95% CI: 16.0–21.3) killed per turbine at control turbines, or 1.6 (95% CI: 1.26–2.04) times more bats killed at control turbines than at deterrent turbines. In other words, 20–53% fewer bats were killed at treatment turbines than at control turbines.

In 2010, Arnett et al. tested for inherent difference between control and deterrent turbines. We found 59 carcasses (n = 37 control, n = 22 deterrent) of 6 species from 1 May to 26 July 2010. During the experiment, 223 carcasses were found (n = 162 control, n = 61 deterrent) of 6 species from 31 July through 9 October 2010. The average per-turbine fatality rate at deterrent turbines was found to be significantly less than at control turbines. Arnett et al. estimated an average of 13.2 bats (95% CI: 11.1–15.3) were killed per turbine at deterrent turbines compared to 23.5 bats (95% CI: 20.4–27.2) killed per turbine at control turbines. This resulted in 1.80 (95% CI: 1.22–2.64) times more bats killed at control turbines on average than at deterrent turbines during the study period; in other words, 18–62% fewer bats killed at deterrent turbines relative to control turbines. However, when considering the inherent differences between treatment and control turbines the effect varies from 2% more to 64% fewer fatalities at deterrent turbines compared to control turbines.

Key Findings for Operational Mitigation Studies & Deterrent Research

The BWEC initiated the first U.S.-based study investigating the efficacy of reducing bat fatalities by raising turbine cut-in speed. We found that by increasing cut-in speed between 5 and 6.5 m/s reduced bat fatalities by up to more than 90% with marginal power loss (≤1% of total annual output). BWEC studies on increasing turbine cut-in speed have resulted in two reports and 1 peer-reviewed journal article in *Frontiers of the Ecology and the Environment*. This research and resulting reports and publications have provided the basis for several new studies on changing cut-in speed to reduce bat fatality, including research to “fine-tune” operational mitigation (i.e., the timing and speed at which turbines need to be curtailed), and is influencing policy discussions and decisions.

The BWEC deterrent research represents a progression from laboratory studies to preliminary field studies, culminating in tests of deterrent devices at fully operational wind facilities. Throughout these tests, we developed more sophisticated deterrent devices that would enable us to project broadband acoustic sound farther and thus create a larger affected area. Our initial laboratory tests proved that we could generate a broadband ultrasonic noise that discouraged bat presence and prevented bats from capturing prey items. We then moved our tests to the field and discovered free-flying bats avoided the affected area and presumably did not habituate to the noise. Our first experiment at an operational wind facility examined the activity of bats at turbines equipped with deterrents and those not equipped with deterrents. In one trial, fewer bats were observed at deterrent-equipped turbines, but the second trial was inconclusive. However, at Locust Ridge, we demonstrated a reduction in bat fatalities at deterrent-equipped turbines.

Acoustic deterrent devices mounted on the nacelle of a wind turbine.

FORTHCOMING DELIVERABLES

We are finalizing a number of study reports, with anticipated completion in fall 2011. These include 1) two pre-construction final reports from the Casselman and South Chestnut Wind Projects (in progress), 2) a pre-construction acoustic monitoring report from the Resolute Wind Project, WY (in review by the BWEC Advisory Committees), a final post-construction fatality report from the Casselman Wind Project (in progress), and a 2-year final report of the deterrent study (in the final stages of review). A number of deliverables also are planned from our current study with USGS, which examines the relationship between post-construction activity and fatality, with expected completion in 2012. We are preparing several manuscripts to be submitted for publication fall 2011 and winter 2012. After completion of our 2-year deterrent report, we will submit a manuscript to a peer-refereed journal. Other manuscripts include a regional assessment of our acoustic monitoring studies and an analysis of our density-weighted model for estimating bat fatalities at wind energy facilities.

NEXT STEPS

The BWEC, in cooperation with the USGS is conducting a post-construction study at two wind energy facilities, in Pennsylvania and Texas, to examine the relationship between acoustic activity recorded at the height of the turbine nacelle, approximately 80 m agl, and fatality. We also will explore the potential to develop useful predictive models of activity and fatality from commonly measured variables (e.g., wind speed and temperature) to assist with fine-tuning operational mitigation. We have several anticipated projects for 2012, including 2 post-construction studies and 2 operational mitigation studies. We also are working with Deaton Engineering to develop a more robust deterrent device and are working with GE and other turbine manufacturers to better design means of mounting the equipment. Deterrent R&D will continue into 2012 and plans for additional deterrent field research are currently scheduled for 2013. We also intend to examine the relationship between pre-construction acoustic data and post-construction fatality data from a number of project sites across the country and will conduct this analysis in 2012. Our next BWEC Science Meeting is scheduled for 10–13 January 2012. We will discuss key research findings since the 2008 meeting, evaluate our research priorities, and develop a research agenda for the coming years.

PARTNERS & FINANCIALS

Currently, the BWEC has over 45 contributing partners, which help support research efforts (Appendix 1). Funding for BWEC activities is provided largely by BCI, AWEA member companies, and federal agencies, primarily DOE and NREL (Appendix 2). BCI's contributions range from 19–58% from 2004–2010. Over the past 8 years, AWEA and NREL contributions have ranged from 28–72% and 10–25%, respectively. The USGS has contributed 29% of revenues in 2011. Overall, salaries for BCI staff comprise the greatest proportion of expenditures, with yearly proportions ranging from 20–43% (Appendix 3). Consulting and contract labor, which includes hiring a statistical consultant to conduct analyses and technicians to collect field data, constitute 16–44% of our expenses. Equipment costs and travel make up 6–31% and 7–20% of expenditures, respectively.

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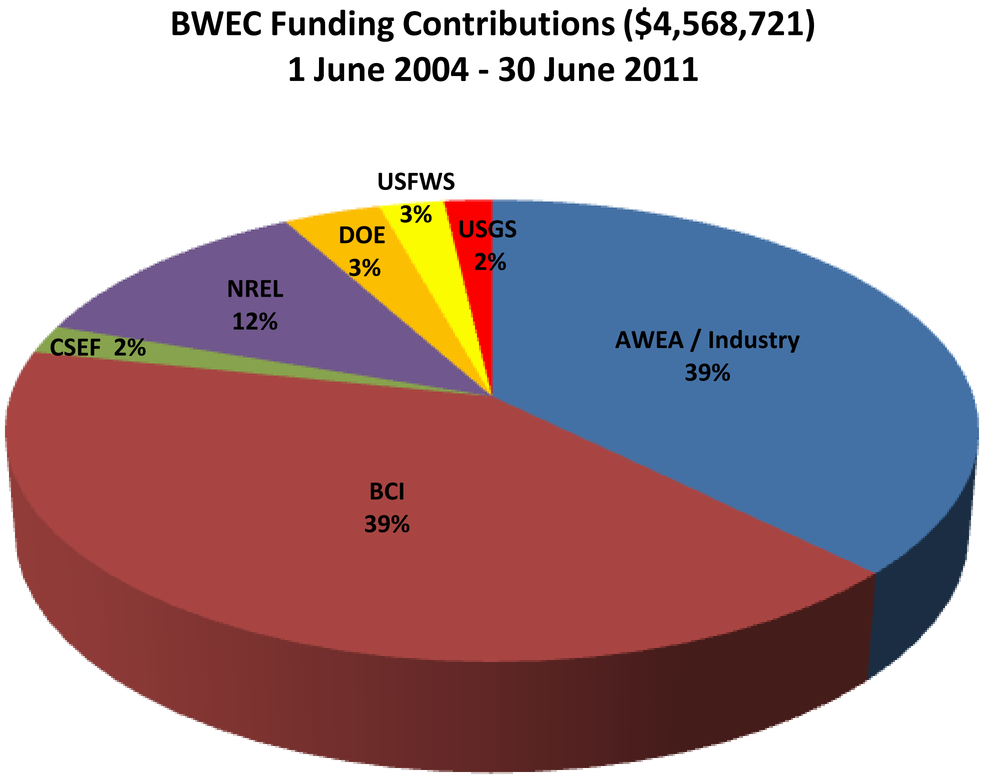
Appendix 1: Funding Partners

Acciona
Adele M. Thomas Charitable Foundation, Inc.
AES Wind Generation
American Wind Energy Association
American Wind Wildlife Institute
Bass Foundation
BP Alternative Energy
Beneficia Foundation
Clean State Energy Funds
Clipper Windpower
Community Foundation for the Alleghenies
Donors to Bat Conservation International
Duke Energy
Edison Mission
Edward Gorey Charitable Trust
Energy and Environmental Ventures II, LLC
Erdman Family Foundation
First Wind
Gamesa
General Electric
Horizon Wind Energy (formerly Zilkha Renewable Energy)
Iberdrola Renewables (formerly PPM Energy)
Invenergy
Massachusetts Technology Collaborative
Merrill Foundation
National Fish and Wildlife Foundation
National Renewable Energy Laboratory
NedPower
New York State Energy Research and Development Authority
NextEra Energy Resources (formerly FPL Energy)
Noble Environmental
Offield Family Foundation
PPM Atlantic Renewable
Rhode Island Renewable Energy Fund
Suzlon
The Hulebak-Rodricks Foundation
The Leo Model Foundation, Inc.
The New York Community Trust
Trans Alta Corporation
TRF - Sustainable Development Fund
U.S. Department of Energy
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. Wind Force
Vestas
Wiancko Charitable Foundation Inc.

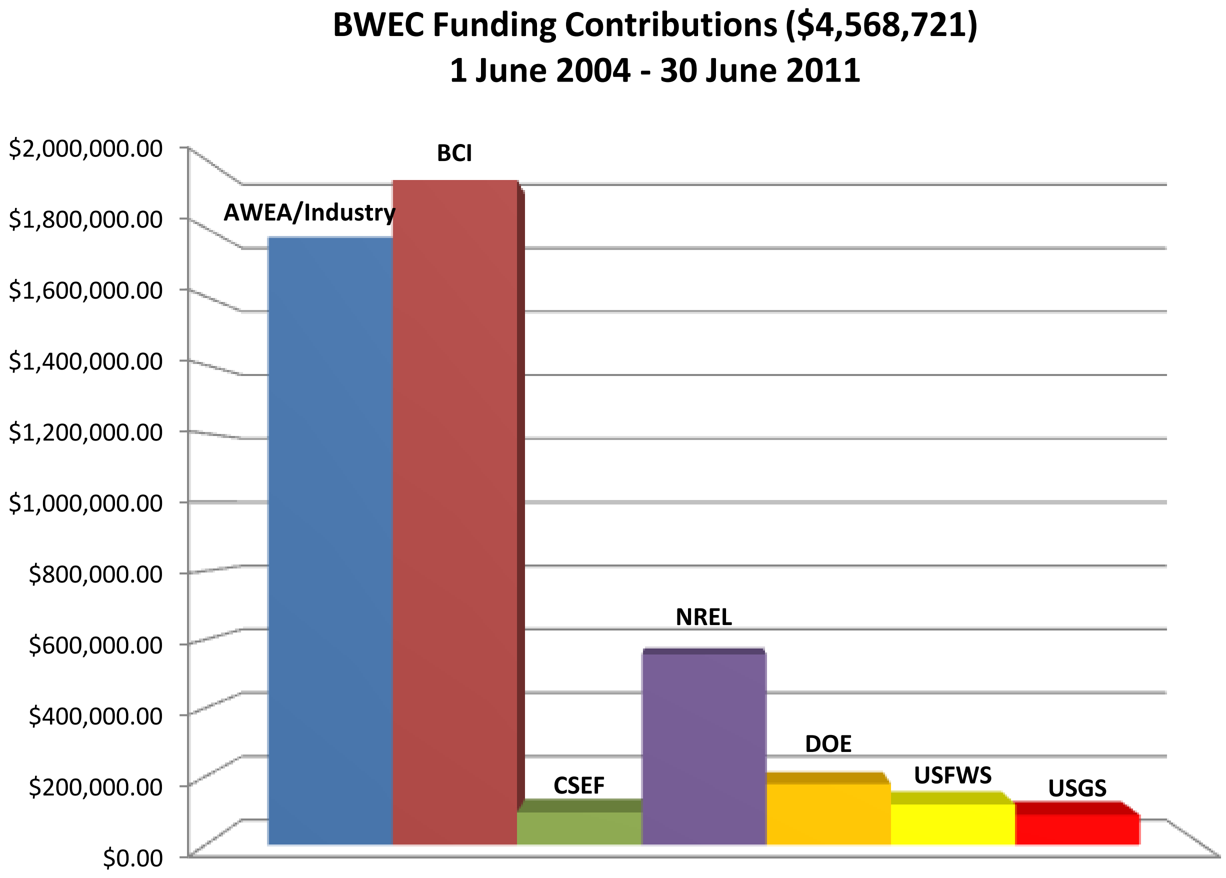
Appendix 2: BWEC Revenues

Appendix 2, Figure 1. Total revenues (a, b), by funding partner, generated for the Bats and Wind Energy Cooperative . AWEA = American Wind Energy Association; BCI = Bat Conservation International; CSEF = Clean State Energy Funds; DOE = Department of Energy; NREL = National Renewable Energy Lab; USGS = U.S. Geological Survey; USFWS = U.S. Fish and Wildlife Service.

(a)



(b)


BWEC Funding Contributions ($4,568,721)
1 June 2004 - 30 June 2011
$2,000,000.00
$1,800,000.00
$1,600,000.00
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$0.00
AWEA/Industry
BCI
CSEF
NREL
DOE
USFWS
USGS

Appendix 3: BWEC EXPENSES

Appendix 3, Figure 1. Total Expenses by funding expense category, for the Bats and Wind Energy Cooperative.