This research guide is intended to be a general introduction to finding authoritative sources of information on environmental science.

For research assistance send an email request to David Hoxie:

hoxiede@ab.edu

1

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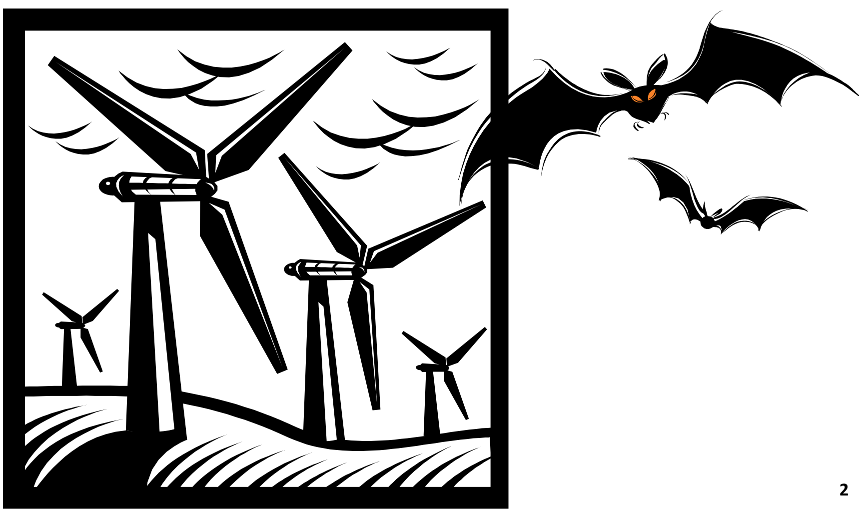
Example topic: Wind Turbines and Bat Fatalities



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1. Encyclopedia articles provide a **broad general overview** of a topic.

2. Books provide a **more in-depth overview** of a topic.

3. Journal articles provide **detailed in-depth information** on a topic.

3

Environmental Science: Research Guide

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  - ***Encyclopedia of Life Sciences*** ***(slides 11-15)***
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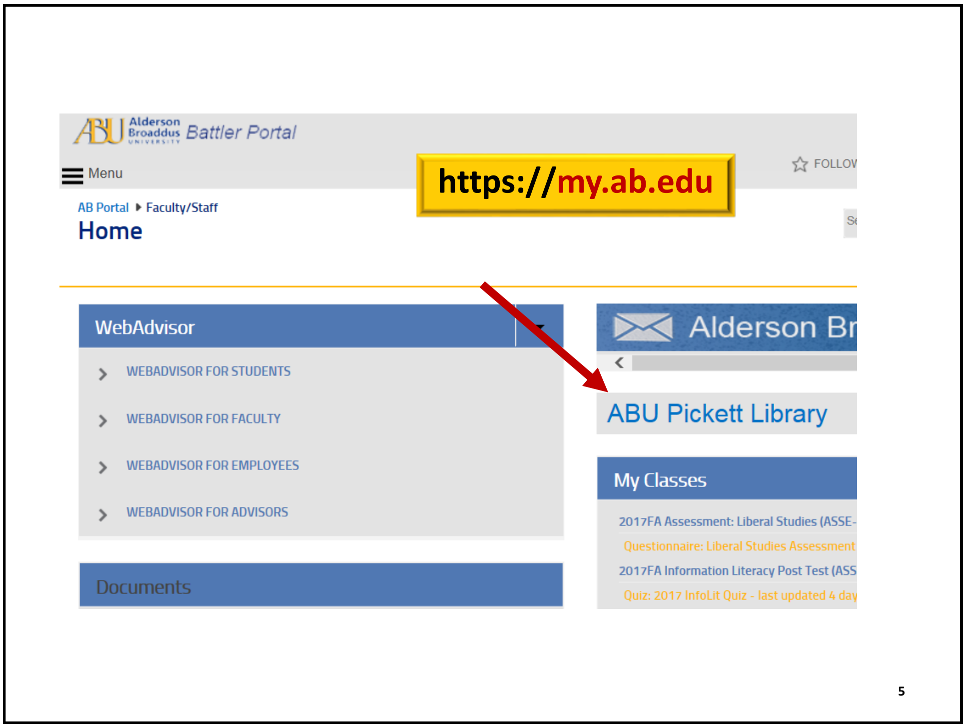
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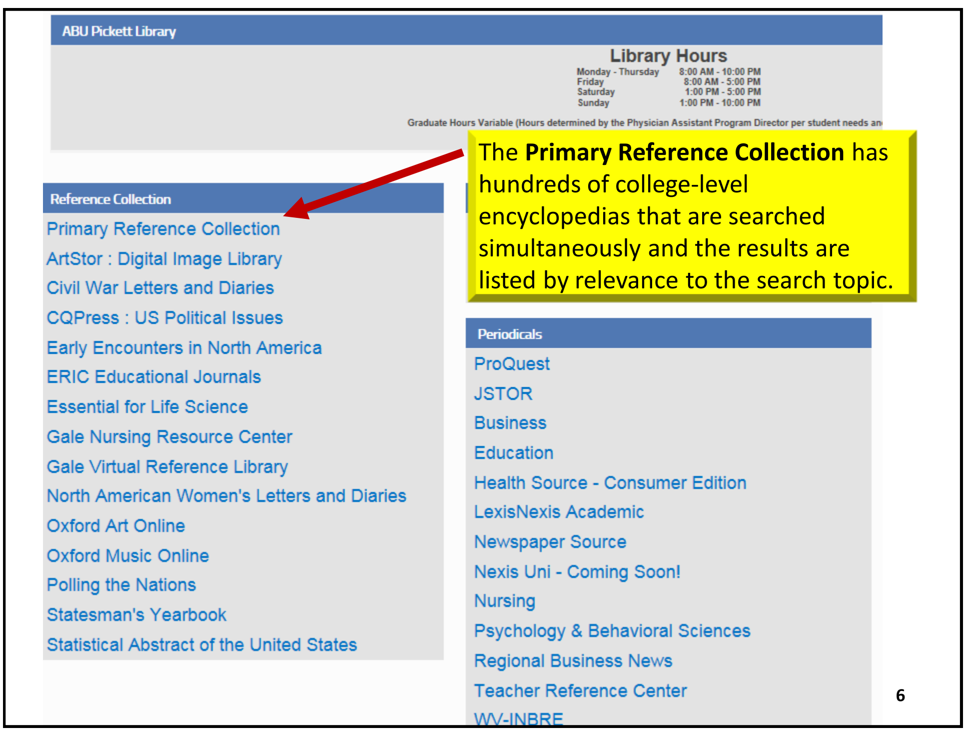
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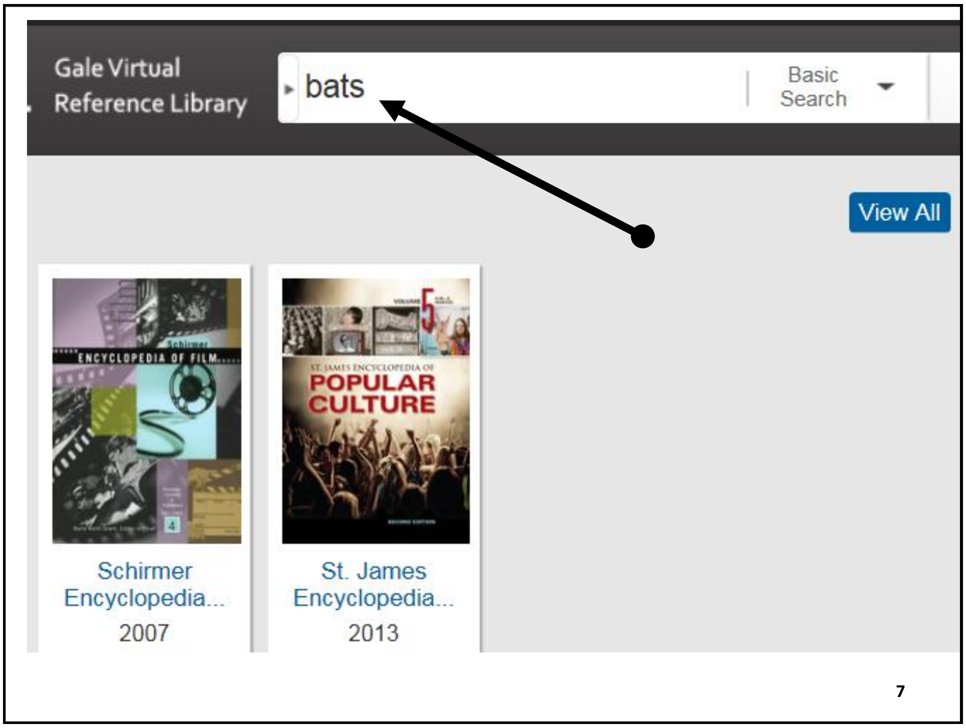
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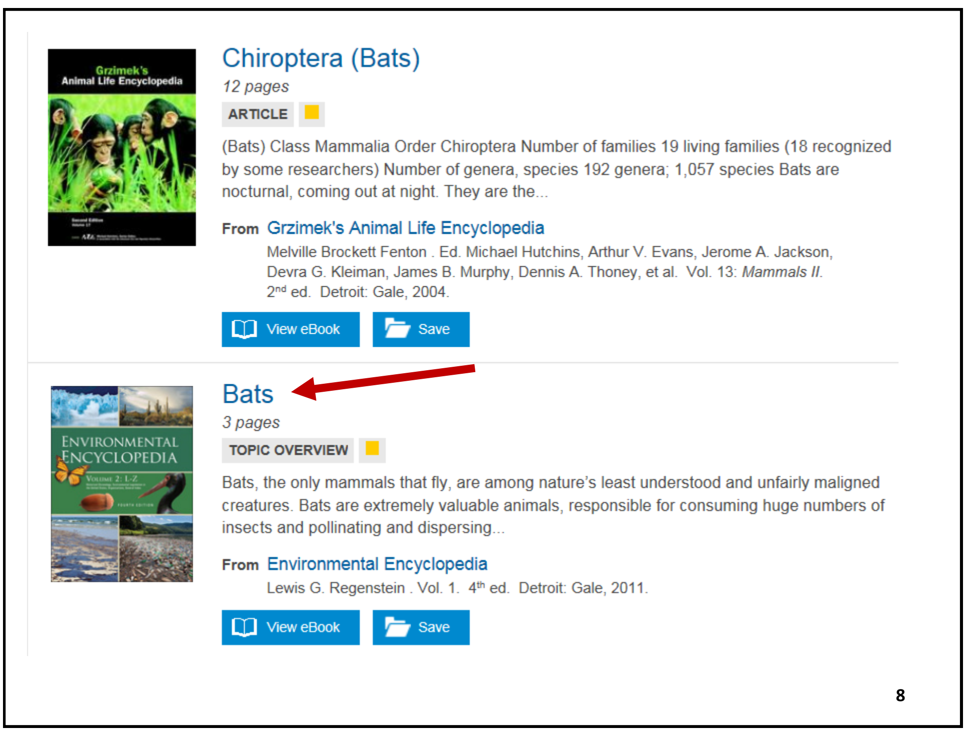
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(Bats) Class Mammalia Order Chiroptera Number of families 19 living families (18 recognized by some researchers) Number of genera, species 192 genera; 1,057 species Bats are nocturnal, coming out at night. They are the...
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Bats, the only mammals that fly, are among nature's least understood and unfairly maligned creatures. Bats are extremely valuable animals, responsible for consuming huge numbers of insects and pollinating and dispersing...
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Lewis G. Regenstein . Vol. 1. 4th ed. Detroit: Gale, 2011.
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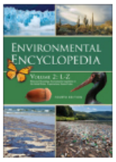

TOPIC OVERVIEW

Bats

Environmental Encyclopedia

Vol. 1. 4th ed. Detroit: Gale, 2011. p144-146.

Lewis G. Regenstein

Bats

Resources

Bats, the only mammals that fly, are among nature's least understood and unfairly maligned creatures. Bats are extremely valuable animals, responsible for consuming huge numbers of insects and pollinating and dispersing the seeds of fruit-bearing plants and trees, especially in the tropics. Yet, superstitions about and fear of these nocturnal creatures have led to their persecution and elimination from many areas, and several species of bats are now threatened with extinction.

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According to Tuttle, a colony of just 150 big brown bats can eat almost 40,000 cucumber beetles in a summer, which "means that they've protected local farmers from 18 million root worms, which cost American farmers $1 billion a year," including crop damage and pesticide costs. Tuttle and his organization suggest that people attract the creatures and help provide habitat for them by constructing or buying bathouses. Nevertheless, bats continue to be feared and exterminated throughout the world. Major threats to the survival of bats include intentional killing, loss of habitat (such as old trees, caves, and mines), eviction from barns, attics, and house eaves, pesticide poisoning, and vandalism and disturbance of caves where they roost. According to Tuttle, "Bats are among the most endangered animals in America. Nearly 40 percent of America's 43 species are either endangered or candidates for the list."

Over a dozen species of bats worldwide are listed by the U.S. Department of the Interior as endangered species, including the gray bat (*Myotis grisescens*) of

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central and southeastern United States; the Hawaiian hoary bat (*Lasiurus cinereus semotus*); the Indiana bat (*Myotis sodalis*) of the eastern and mid-western United States; the Ozark big-eared bat (*Plecotus town-sendii ingens*) found in Missouri, Oklahoma, and Arkansas; the Mexican long-nosed bat (*Leptonycteris nivalis*) of New Mexico, Texas, Mexico, and Central America; Sanborn's long-nosed bat (*Leptonycteris sanborni*) of Arizona, New Mexico, Mexico, and Central America; and the Virginia big-eared bat (*Plecotus townsendii virginianus*) found in Kentucky, North Carolina, West Virginia, and Virginia.

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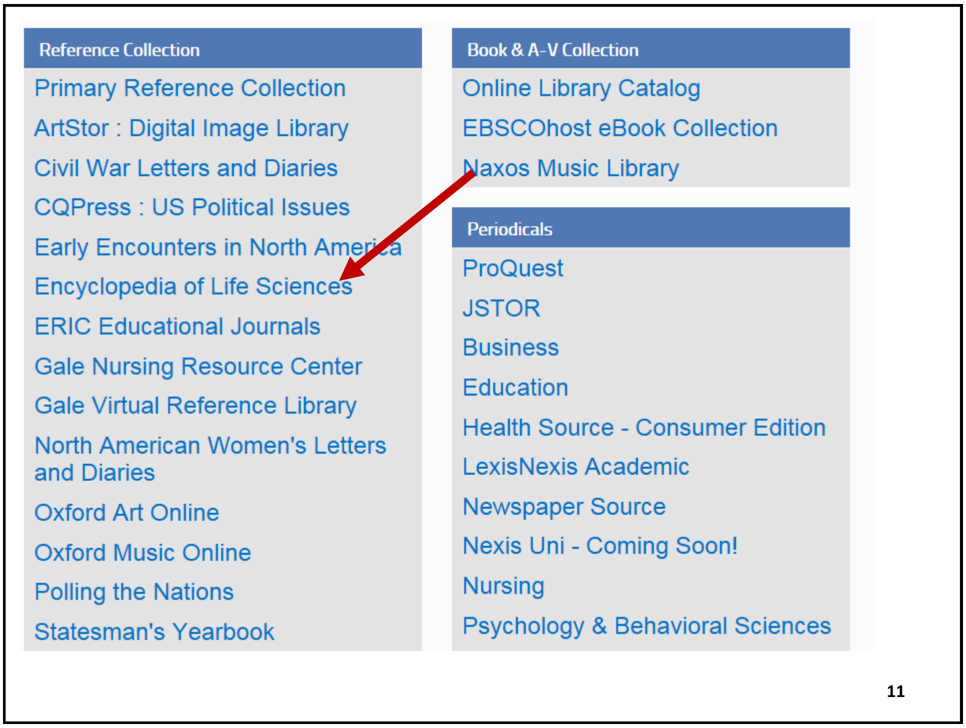
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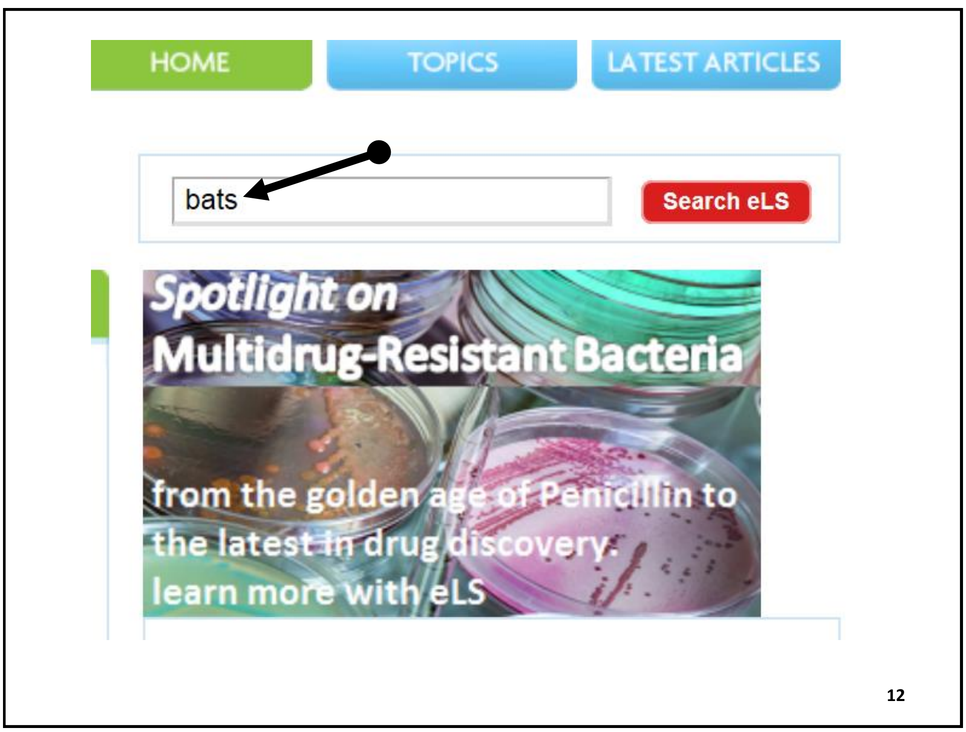
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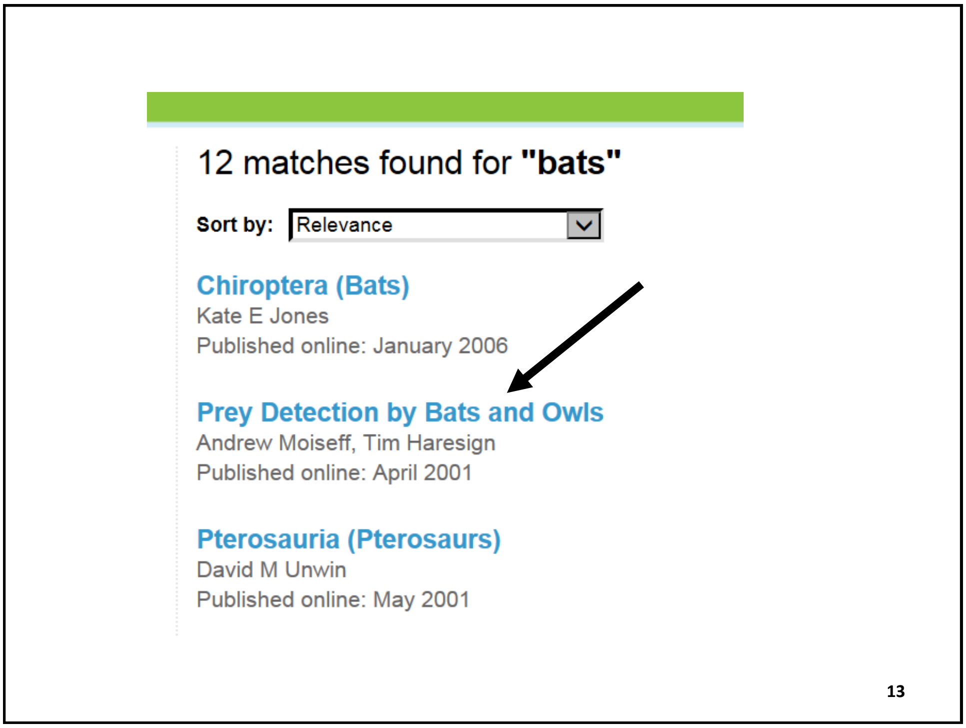
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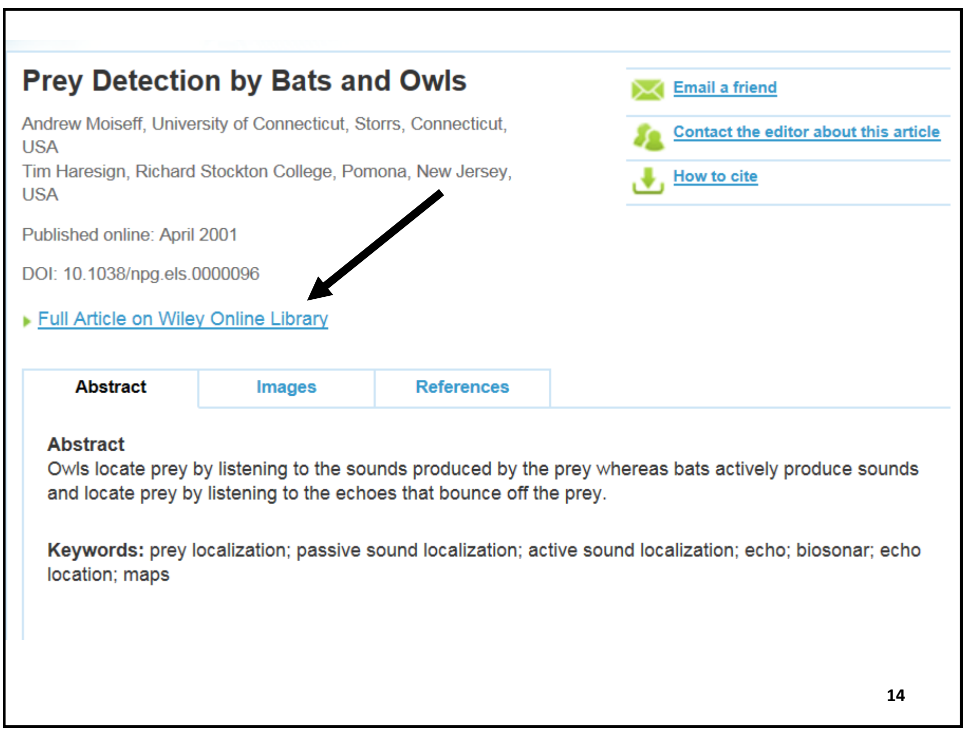
Prey Detection by Bats and Owls
Andrew Moiseff, University of Connecticut, Storrs, Connecticut, USA
Tim Haresign, Richard Stockton College, Pomona, New Jersey, USA
Published online: April 2001
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Abstract
Owls locate prey by listening to the sounds produced by the prey whereas bats actively produce sounds and locate prey by listening to the echoes that bounce off the prey.
Keywords: prey localization; passive sound localization; active sound localization; echo; biosonar; echo location; maps
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Jump to…

Active Biosonar Systems in Echolocating Bats

Whereas owls use passive listening to determine the location of prey, many bats use a different strategy. There are over 900 species of bats, of which a large majority use an active biosonar system for the purposes of echolocation (Figure 1). These bats emit high-frequency sounds using their vocal apparatus. The sounds, or pulses, emitted by the bat interact with objects in the environment and some of the sound is reflected back to the bat. If an object reflects enough sound energy, then this echo will be detected by the bat. The bats use these echoes to navigate through their local environment, and to detect, identify and localize prey. Many different observations and experiments with different species of echolocating bats have shown that through the sole use of their biosonar systems they are able to perceive a detailed three-dimensional acoustical image of their local surroundings. To provide just one example: high-speed, low-light film records have shown that the little brown bat, *Myotis lucifugus*, is able to pursue a moth into dense vegetation and capture the moth, while successfully avoiding the vegetation. See also Chiroptera (Bats)

The capacity to perform tasks such as this requires the bat to be able to extract information about the azimuth, elevation and distance of objects from returning echoes. Most studies of bats' biosonar systems have focused on distance perception abilities, since localization of the azimuth and elevation of objects are presumed to work by mechanisms similar to those found in other mammals. It is interesting to note that horizontal (azimuth) and vertical (elevation) localization has not been studied extensively in bats and it is possible that some mechanisms of localization in these dimensions may be different in echolocating and nonecholocating animals. See also Sensors of External Conditions in Vertebrates

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Edition New expanded and updated ed.
Pub. Info. Cambridge : Open Book Publishers, ©2017.

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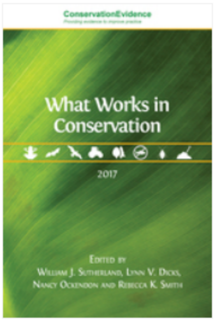

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William J. Sutherland
Lynn V. Dicks
Nancy Ockendon
Rebecca K. Smith

Series: What Works in Conservation
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2. BAT CONSERVATION (pp. 67-94)
Anna Berthinussen, Olivia C. Richardson, Rebecca K. Smith, John D. Altringham and William J. Sutherland

One study in the USA found bat activity within an urban wildlife refuge on an abandoned manufacturing site to be consistent with predictions across North America based on the availability of potential roosts.*Assessment: unknown effectiveness (effectiveness 40%; certainty 20%; harms 0%).*

One site comparison study in the USA found higher bat activity in restored forest preserves in urban areas than in an unrestored forest preserve. One replicated, controlled, site comparison study in the UK found higher bat activity over green roofs in urban areas than conventional unvegetated roofs.*Assessment: unknown effectiveness (effectiveness 50%; certainty 30%; harms 0%).*

We have...

20

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for wind turbines?	
Beneficial	• Switch off turbines at low wind speeds to reduce bat fatalities
Likely to be beneficial	• Deter bats from turbines using ultrasound
Unknown effectiveness (limited evidence)	• Deter bats from turbines using radar
No evidence found (no assessment)	• Automatically switch off wind turbines when bat activity is high • Close off nacelles on wind turbines to prevent roosting bats • Leave a minimum distance between turbines and habitat features used by bats • Modify turbine design to reduce bat fatalities • Modify turbine placement to reduce bat fatalities • Remove turbine lighting to avoid attracting bats

Beneficial

● Switch off turbines at low wind speeds to reduce bat fatalities

Three replicated, controlled studies in Canada and the USA have shown that reducing the operation of wind turbines at low wind speeds causes a

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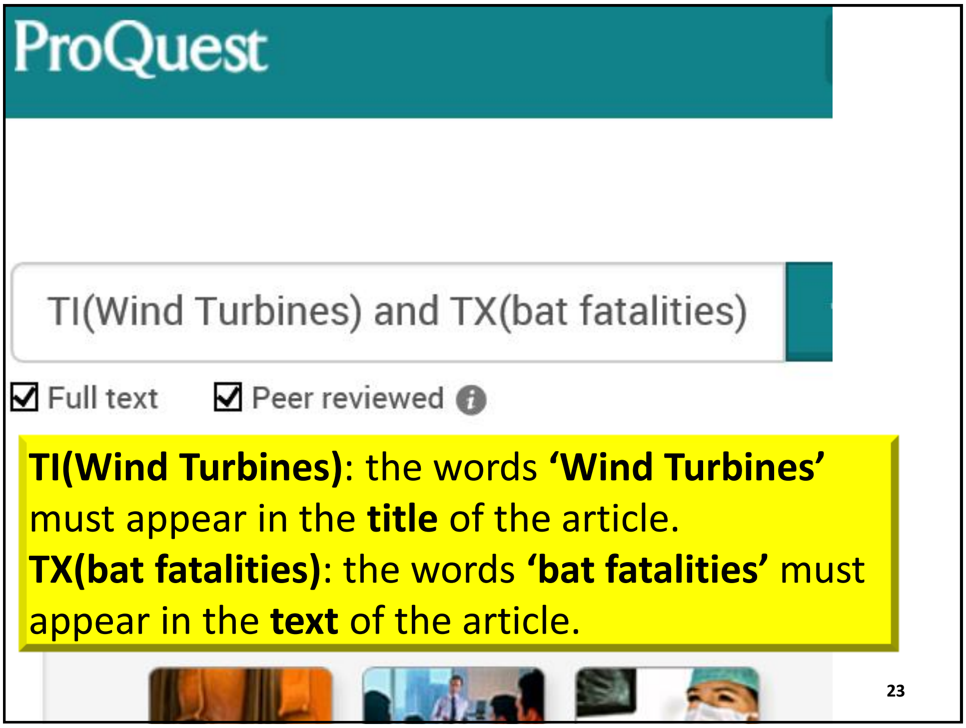
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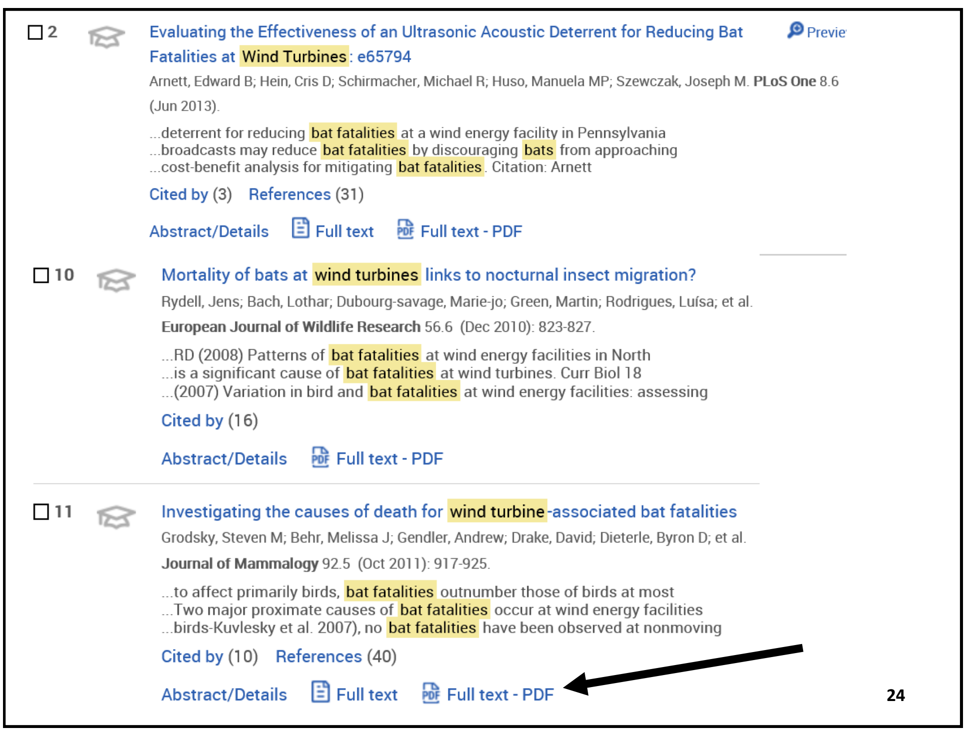
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Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent for Reducing Bat Fatalities at Wind Turbines: e65794
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Arnett, Edward B; Hein, Cris D; Schirmacher, Michael R; Huso, Manuela MP; Szewczak, Joseph M. PLoS One 8.6 (Jun 2013).
...deterrent for reducing bat fatalities at a wind energy facility in Pennsylvania
...broadcasts may reduce bat fatalities by discouraging bats from approaching
...cost-benefit analysis for mitigating bat fatalities. Citation: Arnett
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Mortality of bats at wind turbines links to nocturnal insect migration?
Rydell, Jens; Bach, Lothar; Dubourg-savage, Marie-jo; Green, Martin; Rodrigues, Luísa; et al.
European Journal of Wildlife Research 56.6 (Dec 2010): 823-827.
...RD (2008) Patterns of bat fatalities at wind energy facilities in North
...is a significant cause of bat fatalities at wind turbines. Curr Biol 18
...(2007) Variation in bird and bat fatalities at wind energy facilities: assessing
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Investigating the causes of death for wind turbine-associated bat fatalities
Grodsky, Steven M; Behr, Melissa J; Gendler, Andrew; Drake, David; Dieterle, Byron D; et al.
Journal of Mammalogy 92.5 (Oct 2011): 917-925.
...to affect primarily birds, bat fatalities outnumber those of birds at most
...Two major proximate causes of bat fatalities occur at wind energy facilities
...birds-Kuvlesky et al. 2007), no bat fatalities have been observed at nonmoving
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Bat mortality at wind energy facilities was an unanticipated phenomenon that has become a prominent concern (Barclay et al. 2007; Cryan and Barclay 2009; Kunz et al. 2007b; Kuvlesky et al. 2007). Wind energy facilities have been associated with unprecedented rates of bat mortality in the United States and Canada (Arnett et al. 2008; Johnson 2005) and Europe (Bach and Rahmel 2004; Dürr and Bach 2004). Although impacts of wind energy facilities on wildlife originally were hypothesized to affect primarily birds, bat fatalities outnumber those of birds at most wind energy facilities studied (Arnett et al. 2008; Kunz et al. 2007a; Kuvlesky et al. 2007). A majority of bat mortality in North America involves migratory, tree-roosting bats, including the hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagens*—Arnett et al. 2008). However, relatively high rates of mortality of nonmigratory bats such as the little brown bat (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*) have been observed, specifically in midwestern regions of the United States (Grodsky 2010; Gruver et al. 2009; Jain 2005).

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Although many hypotheses have been proposed to explain why the behavior of bats makes them susceptible to being killed by wind turbines (Cryan and Barclay 2009; Kunz et al. 2007b), this paper addresses the proximate causes exclusively. Two major proximate causes of bat fatalities occur at wind energy facilities: barotrauma and direct collision. Barotrauma at wind turbines occurs as follows: the moving blades of a wind turbine act as an airfoil, creating a region of low pressure along the top of the blade surface (i.e., most convex) and a spiraling vortex near the blade tips, which has a low pressure core (Green 1995; Milne-Thompson 1958). The drop in atmospheric pressure causes injury in the form of internal mechanical damage of lungs and other organs (Elsayed 1997), killing bats that fly through the sudden pressure change.

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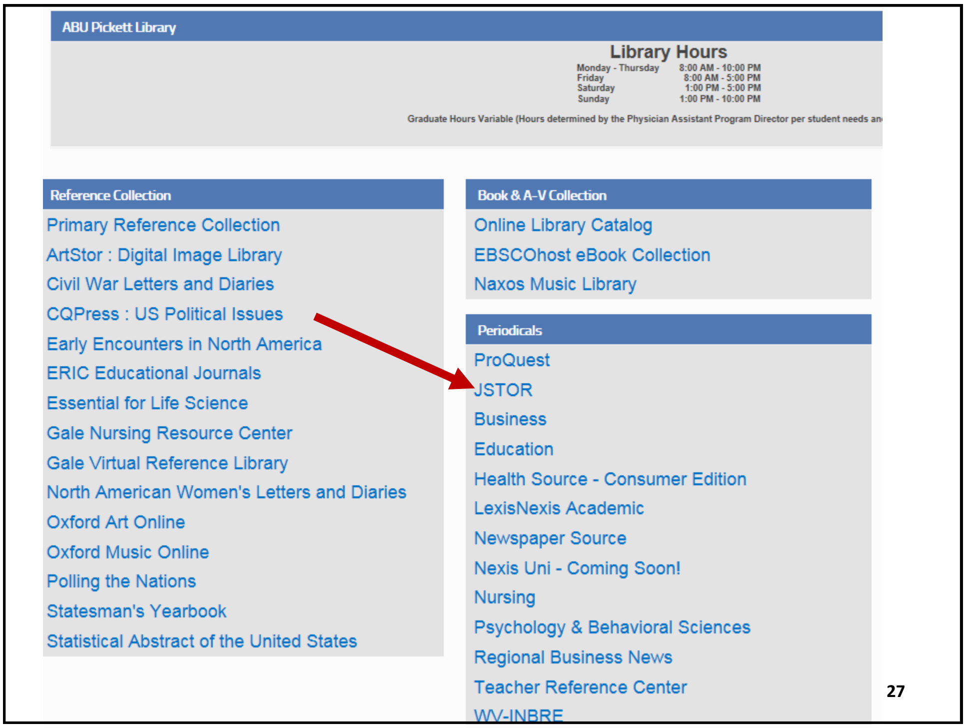
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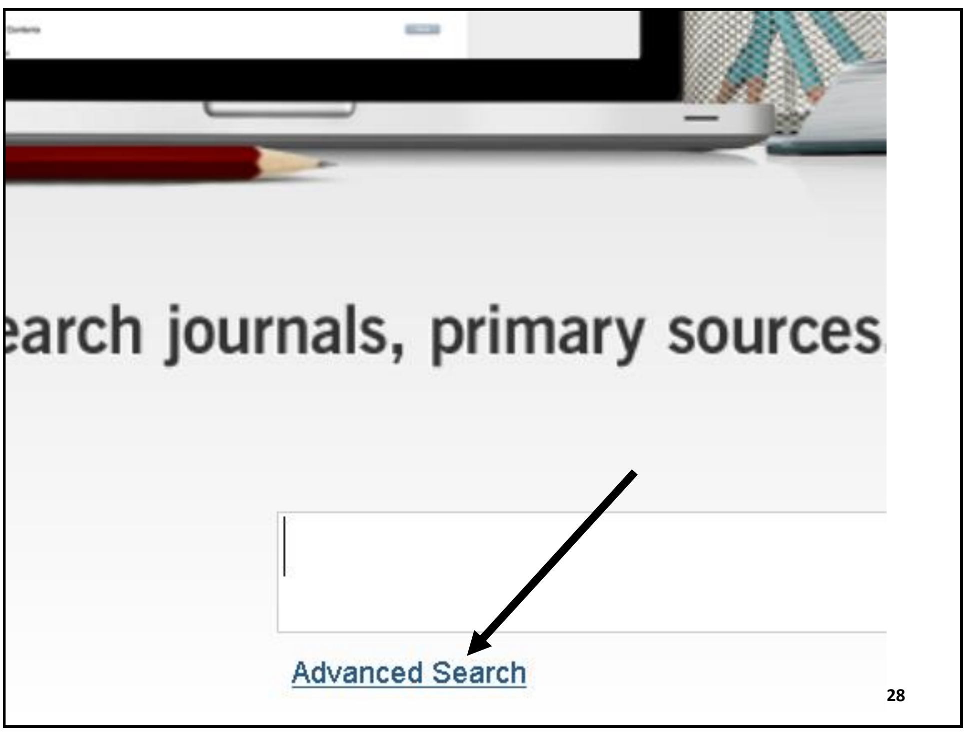
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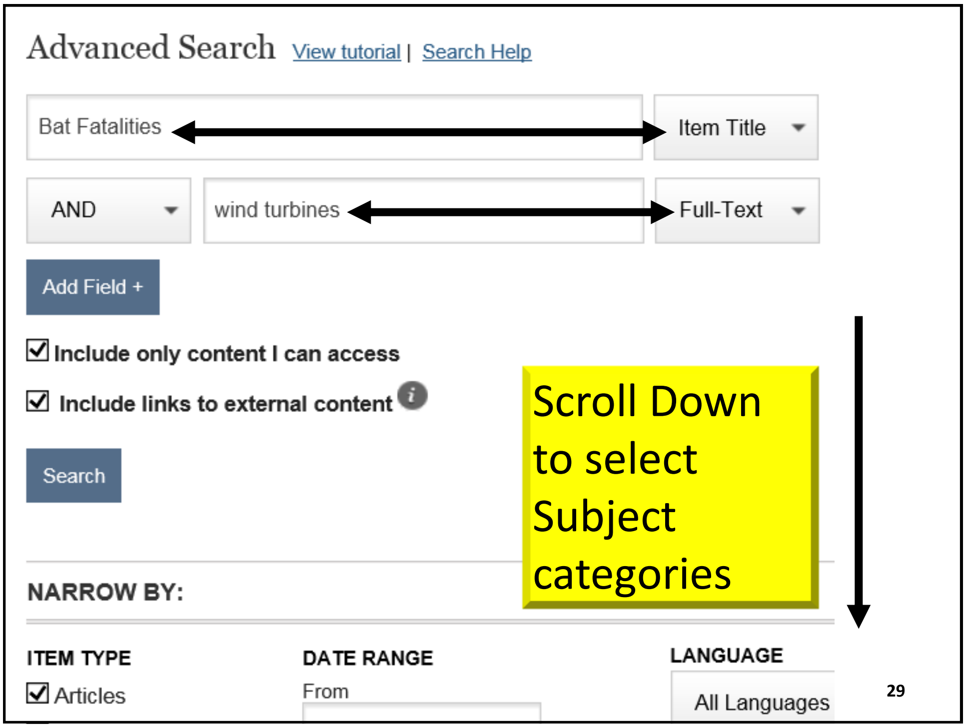
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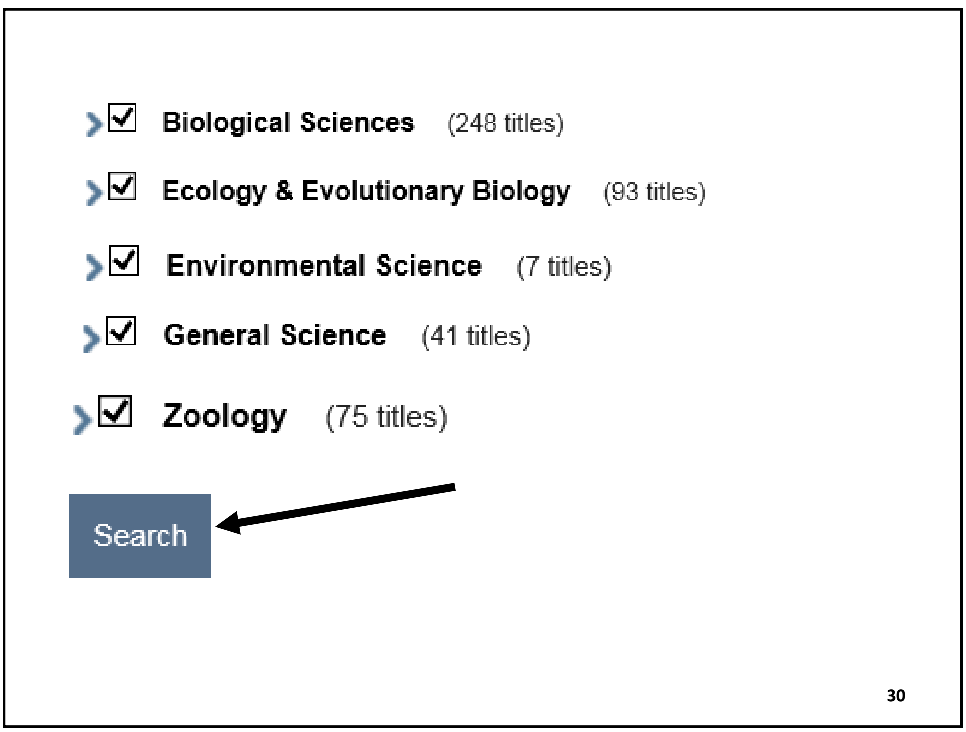
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Paul M. Cryan, Robert M. R. Barclay

Journal of Mammalogy, Vol. 90, No. 6 (Dec., 2009), pp. 1330-1340

...of such mortality on affected species of bats could have long-term population effects (Kunz et al. 2007b). Before this recent problem of **bat fatalities at wind turbines** , collision **fatalities** of bats at other tall anthropogenic structures were rarely reported, and the number of carcasses recovered after **fatality** events...

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☐ Ecological Impacts of Wind Energy Development on Bats: Questions, Research Needs, and Hypotheses

Thomas H. Kunz, Edward B. Arnett, Wallace P. Erickson, Alexander R. Hoar, Gregory D. Johnson, Ronald P. Larkin, M. Dale Strickland, Robert W. Thresher, Merlin D. Tuttle

Frontiers in Ecology and the Environment, Vol. 5, No. 6 (Aug., 2007), pp. 315-324

...**wind** energy facilities, especially along forested ridgetops in the eastern United States. These **fatalities** raise important concerns about cumulative impacts of proposed **wind** energy development on **bat** populations. This paper summarizes evidence of **bat fatalities at wind** energy facilities in the US, makes projections of cumulative **fatalities**...

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To date, no fatalities of state or federally listed bat species have been reported; however, the large number of fatalities of other North American species has raised concerns among scientists and the general public about the environmental friendliness of utility-scale wind energy facilities. For example, the number of bats killed in the eastern US at wind energy facilities installed along forested ridgetops has ranged from 15.3 to 41.1 bats per MW of installed capacity per year (WebTable 1). Bat fatalities reported from other regions of the western and mid-western US have been lower, ranging from 0.8 to 8.6 bats $MW^{-1}yr^{-1}$, although many of these studies were designed only to assess bird fatalities (Anderson *et al.* 1999). Nonetheless, in a recent study designed to assess bat fatalities in southwestern Alberta, Canada, observed fatalities were comparable to those found at wind energy facilities located in forested regions of the eastern US (RMR Barclay and E Baerwald pers comm).

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For the three migratory, tree-roosting species from the Mid-Atlantic Highlands, the projected cumulative fatalities in the year 2020 based on the WinDS model and PJM grid operator queue, respectively, would include 9500 to 32 000 hoary bats, 11 500 to 38 000 eastern red bats, and 1500 to 6 000 silver-haired bats. Given the uncertainty in estimated installed wind turbine capacity for the Mid-Atlantic Highlands and existing data on bat fatalities reported for this region, the above projections of cumulative fatalities should be considered provisional and thus viewed as hypotheses to be tested as improved estimates (or enumerations) of installed capacity and additional data on bat life histories and fatalities become available for this region. Nonetheless, these provisional projections suggest substantial fatality rates in the future. At this time, we have avoided making projections of cumulative fatalities for the entire period from 2006–2020, because of uncertainty with respect to population sizes and the demographics of bat species being killed in this region.

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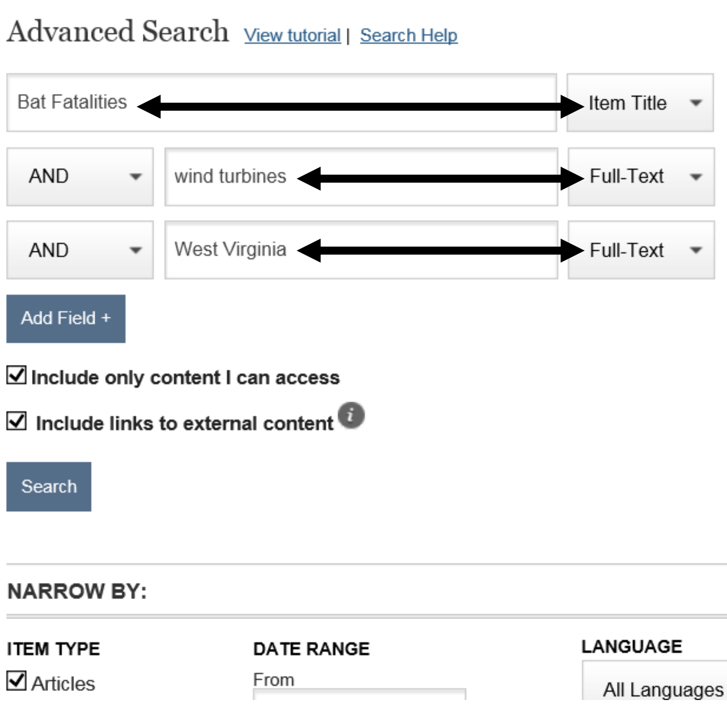

34

☐ Patterns of Bat Fatalities at Wind Energy Facilities in North America

Edward B. Arnett, W. Kent Brown, Wallace P. Erickson, Jenny K. Fiedler, Brenda L. Hamilton, Travis H. Henry, Aaftab Jain, Gregory D. Johnson, Jessica Kerns, Rolf R. Koford, Charles P. Nicholson, Timothy J. O'Connell, Martin D. Piorkowski, Roger D. Tankersley, Jr.

The Journal of Wildlife Management, Vol. 72, No. 1 (Jan., 2008), pp. 61-78

...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** , USA (Kerns and Kerlinger 2004). High **bat fatalities**...

☐ A Preliminary Evaluation on the Use of Dogs to Recover Fatalities at Wind Energy Facilities

Edward B. Arnett

Wildlife Society Bulletin (1973-2006), Vol. 34, No. 5 (Dec., 2006), pp. 144(

...**fatality** searches are provided. (WILDLIFE SOCIETY BULLETIN 3 (5):1440-1445; 2006) Key words bats, Chiroptera, **fatality** searches, Pennsylvania, **West Virginia** , **wind turbines** . Postconstruction carcass searches have been used to estimate combination of these factors. While biases cannot be totally **fatality**...

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35

To my knowledge, dogs have not been trained to find bat carcasses during searches to evaluate fatalities at wind facilities. Herein, I present results of a baseline effort to assess the efficiency of dog–handler teams to recover bat fatalities. My objective was to train dogs to find bat carcasses and conduct pilot studies to determine the search efficiency of dog–handler teams under different vegetation conditions. Based on these trials, I provide recommendations for future research needed to better elucidate patterns and evaluate the biases and efficiency when using dogs for bat fatality searches.

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Table 3. Total number of bat fatalities found and the difference between those found by humans and the dog–handler team ("dogs") during 6 consecutive days of searches for all 5 turbines combined, Meyersdale Wind Energy Center, Pennsylvania, USA, 1–6 Sep 2004.

Date	Dogs	Humans	Difference
1 Sep 2004	14	3	11
2 Sep 2004	15	5	10
3 Sep 2004	3	1	2
4 Sep 2004	7	6	1
5 Sep 2004	5	3	2
6 Sep 2004	1	1	0

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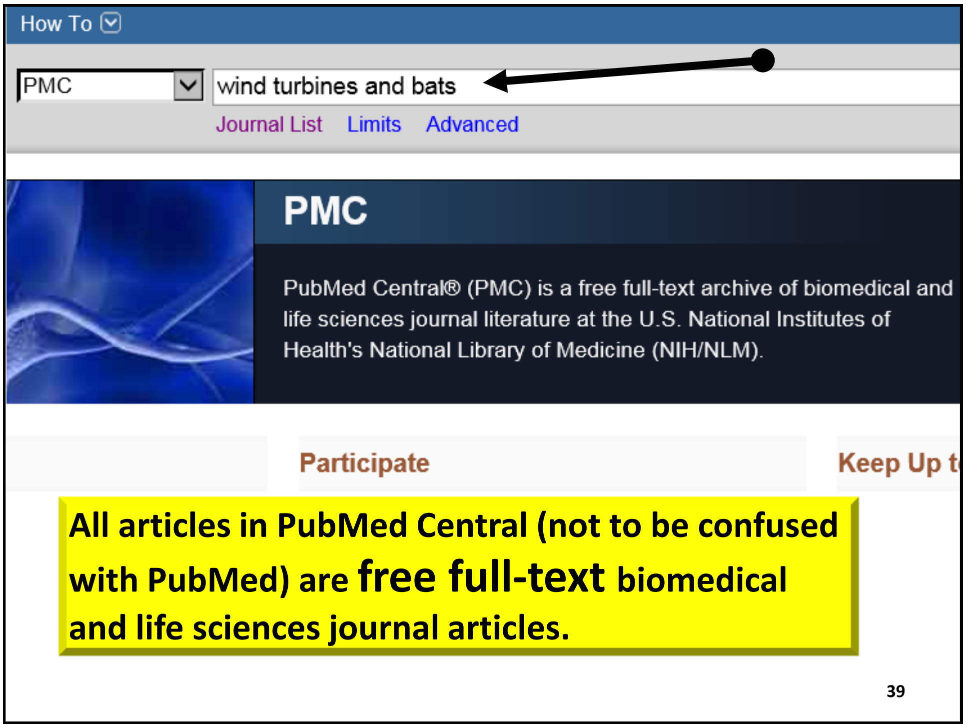
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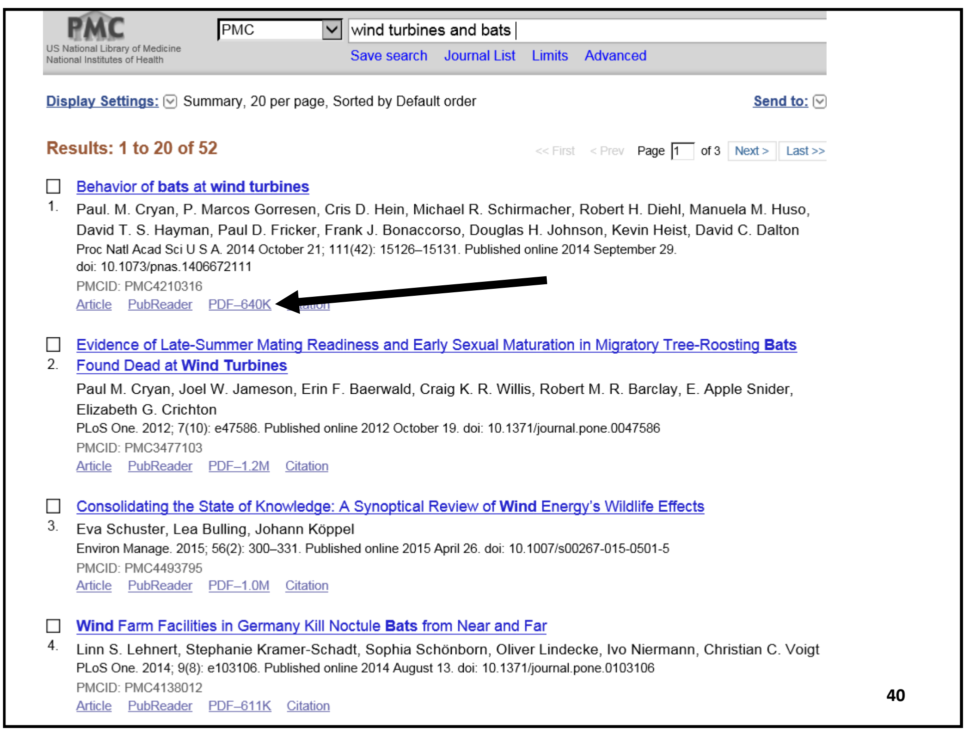
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1. Behavior of bats at wind turbines
Paul. M. Cryan, P. Marcos Gorresen, Cris D. Hein, Michael R. Schirmacher, Robert H. Diehl, Manuela M. Huso, David T. S. Hayman, Paul D. Fricker, Frank J. Bonaccorso, Douglas H. Johnson, Kevin Heist, David C. Dalton
Proc Natl Acad Sci U S A. 2014 October 21; 111(42): 15126–15131. Published online 2014 September 29. doi: 10.1073/pnas.1406672111
PMCID: PMC4210316
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2. Evidence of Late-Summer Mating Readiness and Early Sexual Maturation in Migratory Tree-Roosting Bats Found Dead at Wind Turbines
Paul M. Cryan, Joel W. Jameson, Erin F. Baerwald, Craig K. R. Willis, Robert M. R. Barclay, E. Apple Snider, Elizabeth G. Crichton
PLoS One. 2012; 7(10): e47586. Published online 2012 October 19. doi: 10.1371/journal.pone.0047586
PMCID: PMC3477103
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3. Consolidating the State of Knowledge: A Synoptical Review of Wind Energy's Wildlife Effects
Eva Schuster, Lea Bulling, Johann Köppel
Environ Manage. 2015; 56(2): 300–331. Published online 2015 April 26. doi: 10.1007/s00267-015-0501-5
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4. Wind Farm Facilities in Germany Kill Noctule Bats from Near and Far
Linn S. Lehnert, Stephanie Kramer-Schadt, Sophia Schönborn, Oliver Lindecke, Ivo Niermann, Christian C. Voigt
PLoS One. 2014; 9(8): e103106. Published online 2014 August 13. doi: 10.1371/journal.pone.0103106
PMCID: PMC4138012
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40

energy development | sensory perception | video surveillance | wildlife | wind energy

Bats are long-lived mammals with low reproductive potential and require high adult survivorship to maintain populations (1, 2). The recent phenomenon of widespread fatalities of bats at utility scale wind turbines represents a new hazard with the potential to detrimentally affect entire populations (3, 4). Bat fatalities have been found at wind turbines on several continents (3–6), with hypothesized estimates of fatalities in some regions ranging into the tens to hundreds of thousands of bats per year (4, 6). Before recent observations of dead bats beneath wind turbines, fatal collisions of bats with tall structures had been rarely recorded (7). Most fatalities reported from turbines in the United States, Canada, and Europe are of species that evolved to roost primarily in trees during much of the year ("tree bats"), some of which migrate long distances in spring and late summer to autumn (8). In North America, tree bats compose more than three-quarters of the reported bat fatalities found at wind-energy sites (6, 9), although there is a paucity of information from the

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Significance

Bats are dying in unprecedented numbers at wind turbines, but causes of their susceptibility are unknown. Fatalities peak during low-wind conditions in late summer and autumn and primarily involve species that evolved to roost in trees. Common behaviors of "tree bats" might put them at risk, yet the difficulty of observing high-flying nocturnal animals has limited our understanding of their behaviors around tall structures. We used thermal surveillance cameras for, to our knowledge, the first time to observe behaviors of bats at experimentally manipulated wind turbines over several months. We discovered previously undescribed patterns in the ways bats approach and interact with turbines, suggesting behaviors that evolved at tall trees might be the reason why many bats die at wind turbines.

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43

[HTML] Barotrauma is a significant cause of **bat** fatalities at **wind turbines**
EF Baerwald, GH D'Amours, BJ Klug, RMR Barclay - Current biology, 2008 - Elsevier
Bird fatalities at some wind energy facilities around the world have been documented for decades, but the issue of **bat** fatalities at such facilities—primarily involving migratory species during autumn migration—has been raised relatively recently [1, 2]. Given that ...
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... Although the economic impacts of mass mortality of **bats** associated with WNS appear to be confined, at present, to North America, **wind turbines** are also causing **bat** fatalities in Europe (20), and the potential for WNS to spread to other parts of the world is unknown. ...
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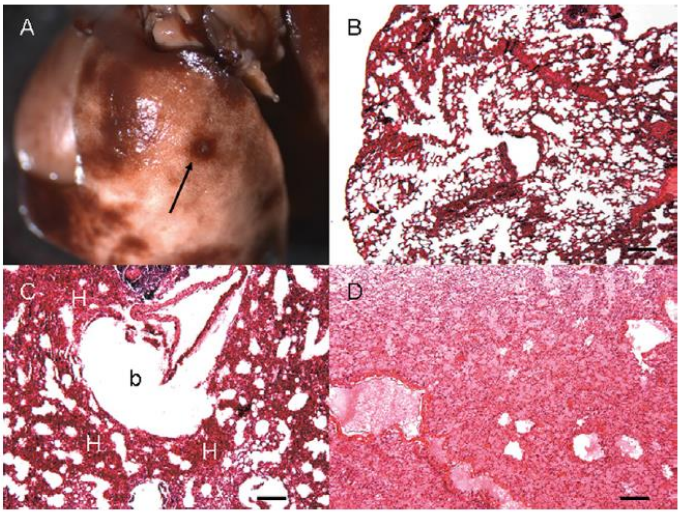

Figure 1. Pulmonary barotrauma in bats killed at wind turbines.
(A) Formalin-fixed *L. noctivagans* lung with multifocal hemorrhages and a ruptured bulla with hemorrhagic border (arrow). Histological sections of bat lungs stained with hematoxylin and eosin (100X). (B) Normal lung of an *L. noctivagans*. (C) Lung of *Eptesicus fuscus* found dead at a wind turbine with no traumatic injury. There is extensive pulmonary hemorrhage (H), congestion, and bullae (b). (D) Lung of *L. cinereus* found dead at a wind turbine with a fracture of the distal ulna and radius. 90% of the alveoli and airways are filled with edema. Bar = 100 µm.

45

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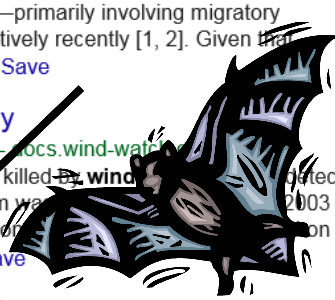

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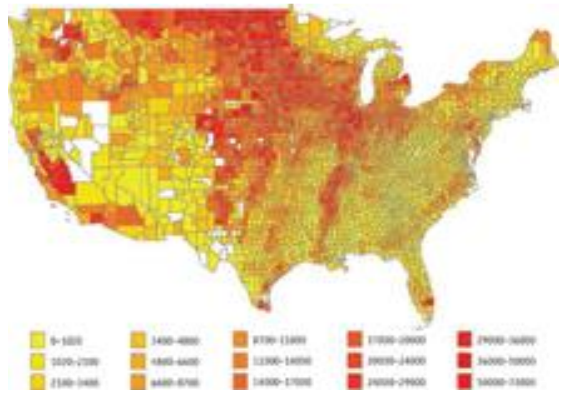

The worth of insectivorous bats.

Estimated annual value of insectivorous bats in the agricultural industry at the county level. Values (×$1000 per county) assume bats have an avoided-cost value of ~ $74/acre of cropland (12). (See SOM for details.)

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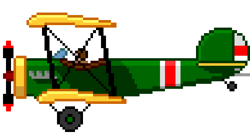
Research Assistance



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