Impacts of wind energy development on bats: implications for conservation



Ed Arnett

Director – Center for Responsible Energy Development Theodore Roosevelt Conservation Partnership and

Department of Natural Resources Management Texas Tech University

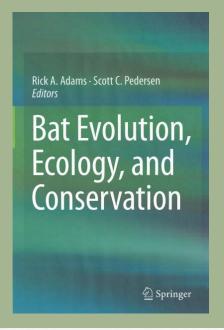
Erin Baerwald

Ph.D. Candidate
Department of Biological Sciences
University of Calgary



Summary of Bats and Wind Energy from 2000-2012

- Background
- Estimates of Bat Fatality
- Patterns and Relationships
 - Temporal and Spatial Patterns
 - Turbine Size
 - Climatic Factors
- Offshore
- Mitigation
- Conclusions, Conservation and Next Steps



Chapter 21 Impacts of Wind Energy Development on Bats: Implications for Conservation

Edward B. Arnett and Erin F. Baerwald

Abstract At a time of growing concern over the rising costs and long-term environmental impacts from the use of fossil flack, wind energy has become an increasingly important sector of the electrical power industry. However, large numbers of bats are being killed at utility-scale wind energy facilities, and these fatalities raise important concerns about cumulative impacts of proposed wind energy development on bat populations. We discuss our current state of knowledge on patties in the USA and Canada, and present findings from mitigation studies. Given the magnitude and extent of thatities of bats worldwich, the conservation implications of understanding and mitigating bat fatalities at wind energy facilities are critically important.

21.1 Introduction

Given a changing climate (Inkley et al. 2004; Schlesinger and Mitchell 1987) and rising costs and long-term environmental impacts from use of fossil fuels, the world is increasingly exploring alternatives to supply emission-free energy (Bernstein et al. 2006; Kunz et al. 2007; McLeish 2002). Wind power is one of the fastest growing renewable energy sources (Fig. 21.1), in part due to recent cost competitiveness with conventional energy sources (Fig. 21.1), in part due to recent cost competitiveness with conventional energy sources, technological advances, and tax incentives Gernstein et al. 2006). At regional to global scales, the effects of wind energy on

B. Arnett (S)

B.B. Artifett (25)
Theodore Roosevelt Conservation Partnership, 3604 Canter Ln., Loveland, CO 80537, USA
e-mail: carnett@trcp.org

F. Baerwald

Department of Biological Sciences, University of Calgary, 2500 University Drive N.W., Calgary, AB T2N 1N4, Canada e-mail: effacewa@ucaleary.ca



Bats and Wind Energy Cooperative (formed by BCI, AWEA, DOE, and USFWS)



Conducted intensive studies from 2004 to present on post-construction fatality and bat interactions with turbines, preconstruction assessments, operational curtailment, and deterrents







Increasing number of studies

Evidence of Late-Summer Mating Readiness and Early Sexual Maturation in Migratory Tree-Roosting Bats **Found Dead at Wind Turbines**

Paul M. Cryan¹*, Joel W. Jameson², Erin F. Baerwald³, Craig K. R. Willis², Robert M. R. Barclay³, E. Apple Snider^{1,4}, Elizabeth G. Crichton⁵

TUhited States Geological Survey, Fort Colles Science Center, Fort Collins, Colonado, United States of America, 2 Department of Biology and Centre for Fores Interdocipilinary Research, University of Winniper, Winniper, Manitoba, Canada, 3 Department of Biological Sciences, University of Calgary, Aberta, Canada Altholed States Forest Service, Statembook Servings, Colonado, United States of America, Sulviversity of Questional, Gutton), Carelland, Australia

Abstract

Understanding airmal mailing systems is an important component of their conservation, yet the precise mailing times for many species of bats are unknown. The airm of this study was to better understand the details and timing of reproductive events in species to that such most frequently at wis inform connervation; strategies. We examined the reproductive events in species to that such earth of the control of the

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leceived April 24, 2012; Accepted September 14, 2012; Published Oct This is an open-access article, free of all copyright, and may be freely repro-any lawful purpose. The work is made available under the Creative Comm

A Large-Scale Mitigation Experiment to Reduce Bat

ERIN F. BAERWALD, Department of Biological Sciences, University of Calgary, Calgary, AB T2N 1N4, Canada

ROBERT M. R. BARCLAY, Department of Biological Sciences, University of Calgary, Calgary, AB T2N 1N4, Canada

Fatalities at Wind Energy Facilities

JASON EDWORTHY, Transilia Wind, Calgary, AB T2P 2M1, Cenada MATT HOLDER, Transilia Wind, Calgary, AB T2P 2M1, Canada

Behavioral Responses of Bats to Operating Wind Turbines

JASON W. HORN, ¹ Grove for Ecology and Concernation Biology, Boston University, Department of Biology, 5 Committeen Street, Busin, 34d 02215, USA

EDWARD B. ARNETT, Bar Consequence International, P.O. But 182900, Annua, TX 78718, UEA

Management and Conservation Article

THOMAS H. KUNZ, Center for Ecology and Construction Biology, Boston University, Department of Biology, 3 Commission Street,

ARSTRACT Wind power is one of the lateral garwing actions of the enemy indicate; Rocert under hear exported large transfers of suggester transmission, but may be all the artifers schemed power factions, opposed is not excent Natural Stean. We used thousand related (100) contracts in one the fight behavior is trans arising device more with the artising under it profile; restores the statemathy contract in the statemath observed with an and when the profile restores the statemathy contract in the statemath observed with the independently at explanational light sources. We conducted the study at the Mountainer Ward Enemy Center in Tarker Course, West Vispinia, USA, where hundreds of migratury too buts have been found, inhand or dead beneath wind turbines. We exceeded egild) Fluor cossus of TR video of operating outlines from which we noward abstock, direction, and types of light maneures of bein, high, and insects. We observed him retroits foregoing reus operating subjects, either than emply passing through subject size. Our medius isolicus that how 1) approached both retaining and someousing blades, 2) followed or west trapped in blade top versions. 3) inscretigated the

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The Journal of Wildlife Management 75(5):1103-1114; 2011; DOI: 10.1002/swmg.147

Patterns of Activity and Fatality of Migratory Bats at a Wind Energy Facility in Alberta, Canada

ERIN F. BAERWALD, Department of Biological Sciences, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta,

ROBERT M. R. BARCLAY, Department of Biological Sciences, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta,

A Preliminary Evaluation on the Use of Dogs to

Recover Bat Fatalities at Wind Energy Facilities

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6-day teasity search that at 5 turbines at Mayersonia. The dog-handler teams found 45 bet cercases, of which only 42% in = 10,

seem found dusting the series period by homers. An both halls human's found fewer calculoses as segetation height and density increased, and educy-handler seams seed efficiency variated high. Recommendation for solutions and efficiency when using sopper for the fetally secretaria are provided. (MEDLIES SOCIETY BILLETIN 349):1440-1445-2000(

omsylvania, West Virginia, wind turbines.

EDWARD B. ARNETT, Par Conservation International Austin, TX 78746, USA

Peer Edited: From the Field

Abstract

ies of migratory bats at some wind energy facilities impetus to study bat migration at fine spatial and

on et al. 2003. are biased by he removal of wer conditions et al. 1993. rinally designed ction fatality frequent search other efficiency been adequately

combination of these factors. While biases cannot be totally avoided during field research, careful study design and analyses are important for limiting bias (Gutzwiller 1990).

To my knowledge, dogs have not been trained to find but 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 but fatalities. My objective was to train dogs to find but carcasses and conduct pilot studies to determine the search efficiency of dog-handler teams under different vegetation condition Based on these trials, I provide recommendations for future research needed to better chicidate parterns and evaluate the biases and efficiency when using dogs for but fatality searches.

Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document



Thomas H. Kunz, Edward B. Arnett, Brian M. Cooper, Wallace P. Erickson, Ronald P. Larkin, Todd Mabee, Michael L. Morrison, M. Dale Strickland, and Joseph M. Szewczak

Journal of Wildlife Management 71(8): 2449-2486; 2007

Research Article

Patterns of Bat Fatalities at Wind Energy Facilities in North America

EDWARD B. ARNETT, 1 But Conservation International, Austin, TX 78746, USA

W. KENT BROWN, Terrestrial and Aquatic Environmental Managers Ltd., Calgary, Alberta T3C 3G9, Canada WALLACE P. ERICKSON, Western EcoSystems Technology, Inc., Cheyenne, WY 82070, USA

JENNY K. FIEDLER, Tennessee Valley Authority, Regional Natural Heritage Program, Knowville, TN 37902, USA

BRENDA L. HAMILTON, BLH Environmental Services, Pincher Creek, Alberta TOK 1W0, Canada

TRAVIS H. HENRY, Tennessee Valley Authority, Regional Natural Heritage Program, Knowville, TN 37902, USA AAFTAB JAIN, I Inwa Cooperative Fish and Wildlife Research Unit, Inva State University, Ames, IA 50011, USA

GREGORY D. IOHNSON, Western EcoSostems Technology, Inc., Chewanse, WY 82070, USA JESSICA KERNS,3 Appalachian Laboratory, University of Maryland, Fruthurg, MD 21532, USA

ROLF R. KOFORD, United States Geological Survey, Ionas Cooperative Fish and Wildiffe Research Unit, Ionas State University, Ames, IA 50011, USA CHARLES P. NICHOLSON, Tennesse Valley Authority, Regional Natural Heritage Program, Knavville, TN 37922, USA

TIMOTHY J. O'CONNELL, Department of Natural Resource Easings and Management, Ollahoma State University, Scillwater, OK 74078, USA MARTIN D. PIORKOWSKI, Department of Zeology, Oklahoma State University, Scillwater, OK 74078, USA ROGER D. TANKERSLEY, JR., Tennessee Valley Authority, Regisnal Natural Heritage Program, Knowille, TN 37902, USA

70 ABSTRACT Wind has become one of the fastest growing sources of ensemble energy worderlies, but widespread and often extensive fastilities of but have increased sources regarding the impact of wind energy development as the said often whileful. We specificated available missensition on particum of the fatistic tens to reason of 21 postconversion delign relates conducted it Tokkelin in 5 United States regions and one Considue province. Destination of impacts, followed and treve-orders fastistic tensy tokes (Linear shortest) likeling by 2 turbose was consistent among stacks. For infection, shortly all post tensor income product in the summer particular for infection, and product in the summer product in the summer particular for infection of the production of the productio coinciding with migration of laisatines and other species. A notable exception was documented fatalities of pregnant female Beaulian frec-tabled buts (Tadorido throniciosis) in May and June at a facility in Oklahoma, USA, and female siber-bained buts (Laisatyperies insorticagens) during spring in Tennessee, USA, and Alberta, Canada, Most radios reported that fatalities weighted underday across settleries and during spring in Tennessee, USA, and Alberta, Canada, Most radios reported that fatalities weighted and individually across settleries and although the highest number of fatalities was often found near the end of turbine strings. Two studies conducted simultaneously in the same region documented similar timing of fatalities between sites, which suggests broader patterns of collisions dictated by weather, prey abundance, or other factors. None of the studies found differences in bat fatalities between turbines equipped with lighting required by the Federal Aviation dministration and turbines that were unlit. All studies that addressed relationships between but fatalities and weather patterns found that most ats were killed on nights with low wind speed (<6 m/sec) and that fatalities increased immediately before and after passage of storm fronts. Feather patterns may be predictors of but activity and fatality; thus, mitigation efforts that focus on these high-risk periods could reduce but fatality substantially. We caution that estimates of bat fatality are conditioned by length of study and search interval and that they are biased in relation to how searcher efficiency, scavenger removal, and habitat differences were or were not accounted for. Our review will assist manage tanding unifying and unique putterns of bat fatality, biases, and limitations of exi will aid in designing future research needed to develop mitigation strate ([OURNAL OF WILDLIFE MANAGEMENT 72(1):000-000; 2008) ategies for minimizing or eliminating but fatality at wind facilitie

KEY WORDS but fatality, fatality searches, North America, wind energy facilities, wind turbines.

As concerns about climate change (see review in Inkley et al. 2004) and increasing costs and long-term environmental impacts from the use of fossil fuels have heightened (McLeish 2002), wind has become an increasingly impor-tant sector of the energy industry and one of the fastest growing sources of renewable energy (Pasqualetti et al. 2004). Wind-generated electricity is renewable and generally considered environmentally clean, and recent technological advances and tax subsidies have allowed comme wind generation to compete with energy produced from

¹ E-mail: earnett@batton.org
² Present address: Carry and Kerlinger, Syracus, NY 13224, USA
³ Present address: Western Ecosystems Technology Inc., Isbaca, NY 14850, USA
⁴ Present address: Carnell Lab of Ornithology, Isbaca, NY 14850, USA

2002). Unfortunately, fatalities of bats have been recorded at wind facilities worldwide, including Australia (Hall and Richards 1972), North America (Johnson et al. 2003a, b. 2004; Fiedler 2004; Arnett 2005), and Europe (Ahlen 2002, Bach and Rahmel 2004, Dürr and Bach 2004, Brinkman 2006). Small numbers of bats were first recorded in the United States at wind energy projects in California, USA, during avian fatality searches (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, USA (Kerns and Kerlinger 2004). High bat fatalities continued at the Mountaineer facility in 2004, and large kills also have been reported at facilities in Pennsylva-

fossil fuels and nuclear power (Gine 1995, Redlinger et al.

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The Wildlife Society



Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat

Possible Explanations Why Bats Are Being Killed by Wind Turbines?



(from Kunz et al. 2007, Cryan and Barclay 2009)

Proximate Causes (how killed)

Ultimate Causes (why killed)

- Random
- Coincidental (e.g., susceptible during migration)
- Attraction
 - Roost attraction
 - Landscape attraction
 - Blade motion attraction
 - Acoustic attraction
 - Insect aggregation
 - Mating attraction (tree bats)







New studies indicating roost attraction and mating hypotheses may explain fatalities, at least for migrating tree bats

Composition of Fatalities





- 21 of the 47 species N of Mexico have been found killed by turbines
- Heavily skewed to migratory tree bats (78%)
- Up to 60% of fatalities at some sites in the eastern & Midwest U.S. are little brown bats, big brown bats, and tricolored bats
- Brazilian free-tailed bats can be common where they occur in the Southwest U.S.



- To date, two endangered species has been <u>found</u> at wind facilities in the U.S.. Indiana bats and Hawaiian hoary bats
- Future take is uncertain, given projected expansion of wind



Future species listings?



Significance of Bat Fatalities



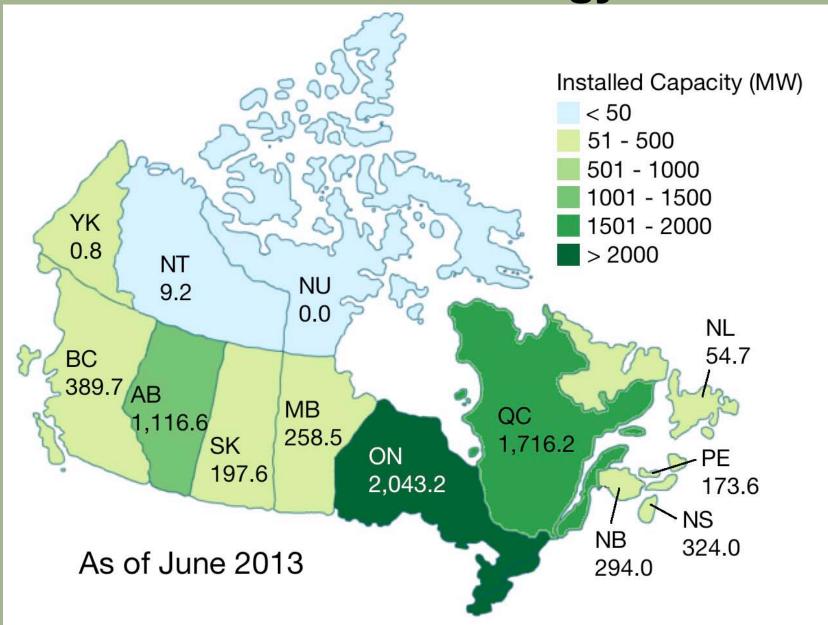
- Species experiencing highest fatalities have little or no protection
- Some species of bats are already in decline (e.g. Eastern red bats in three Midwestern States) (Whitaker et al. 2002, Carter et al. 2003, Winhold et al. 2008, Frick et al. 2010 [white-nosed syndrome])
- Turbines are killing prime breeding age adults and bats breed very slowly
- While population impacts are unknown, considerable concern about cumulative impacts as wind energy expands...



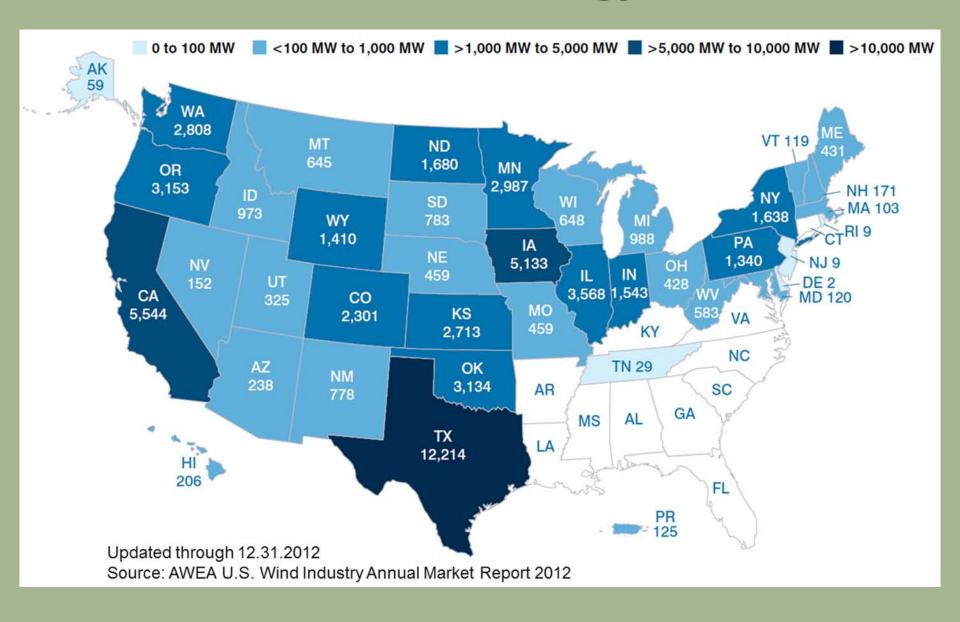
Can these species of bats sustain such rates of additive mortality when considering cumulative effects?



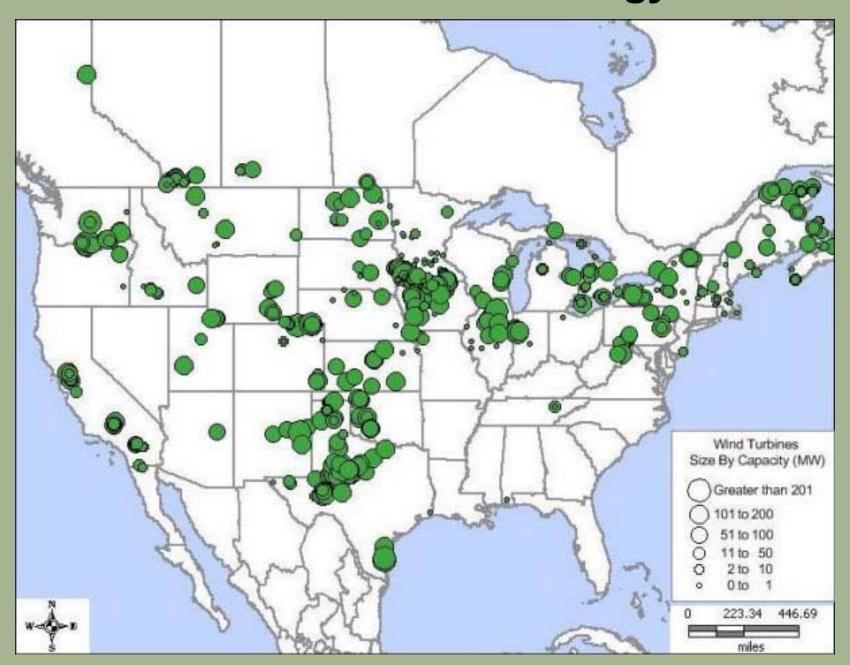
Distribution of wind energy in Canada



Distribution of wind energy in the U.S.

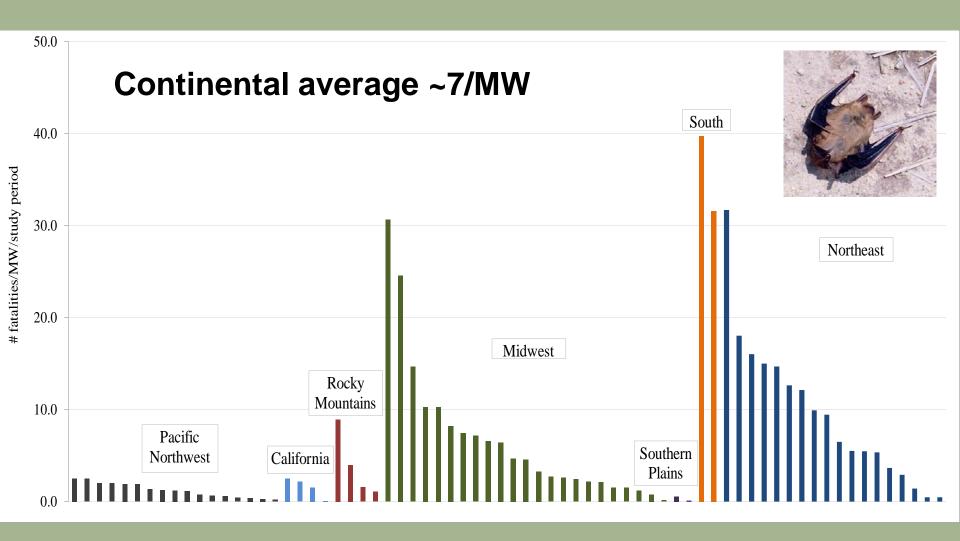


Uneven distribution of wind energy facilities



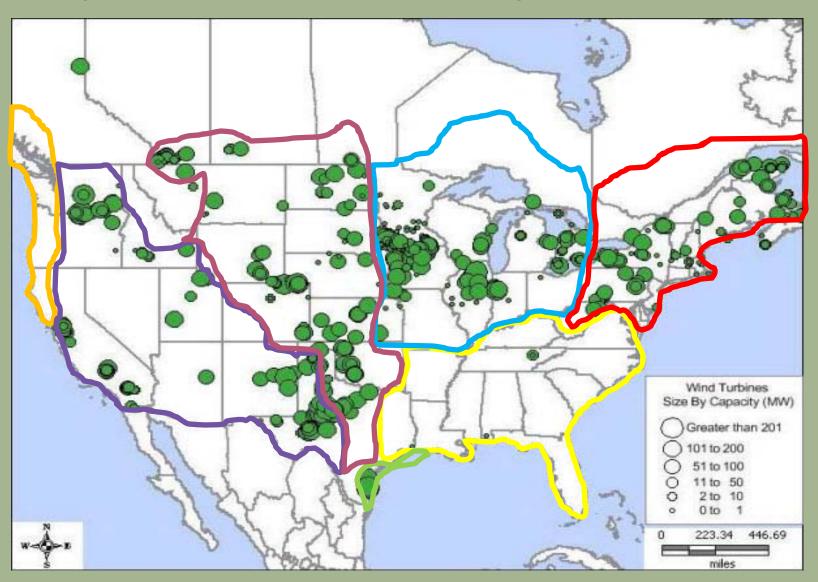
U.S. and Canada Regional Bat Fatality Estimates

(From WEST Inc. and EB Arnett, unpublished data; includes data from Arnett et al. 2008 [~12/MW])



Cumulative fatalities in the U.S. and Canada

Regions delineated based on coarse vegetative conditions...



Assumptions:

- Fatality rates from regional studies are representative of all facilities in a given region
- Fatality rates are constant from year-toyear without mitigation or behavioral modification



Regional Bat Fatalities: 2000-2011

REGION	RANGE OF BAT FATALITIES
Great Basin/Southwest Range	62,021 - 107,017
Great Plains	363,202 - 739,180
SE Mixed Forest	6,866 - 12,895
NE Deciduous Forest	124,187 — 214,876
Western Temperate Forest	453 – 933
Mid-West Forest-Agriculture	289,564 - 627,362

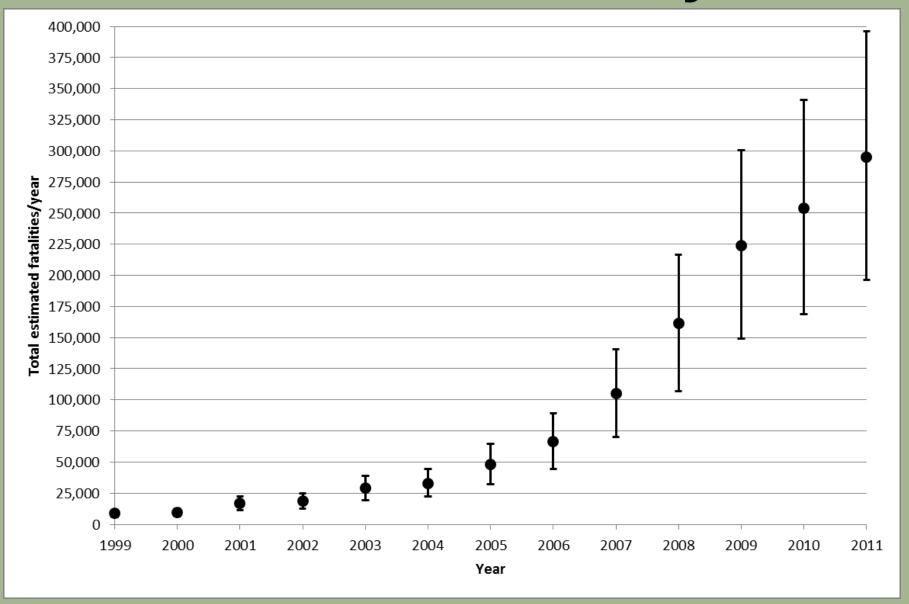
Cumulative Bat Fatalities:

Developed a weighted mean by region and it's installed capacity, then summed to calculate cumulative fatalities for U.S. and Canada

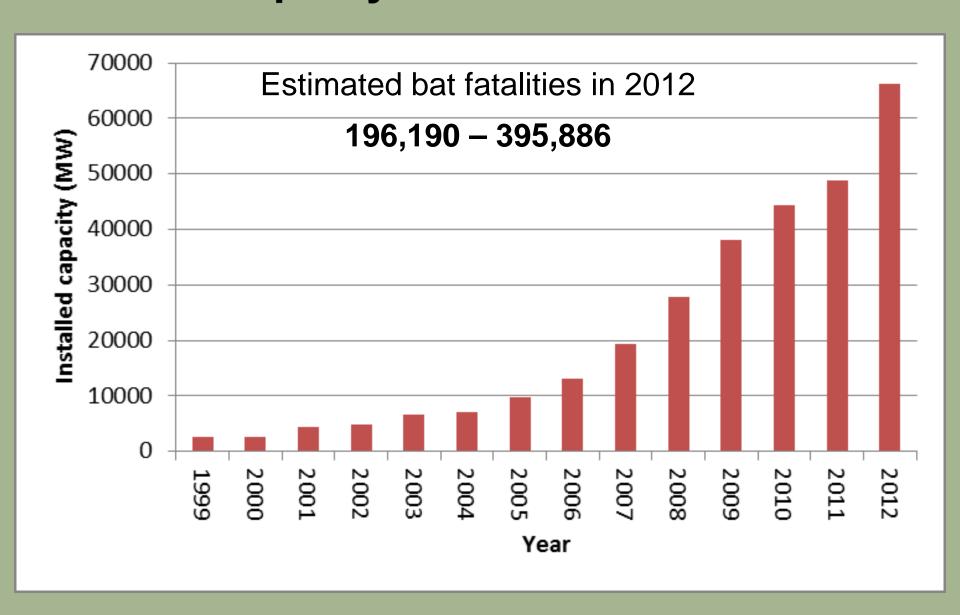


Mean bat fatalities from 2000-2011 = 1,261,622 (3.34-5.88/MW) 840,486 - 1,690,696

Estimates of bat fatalities/year

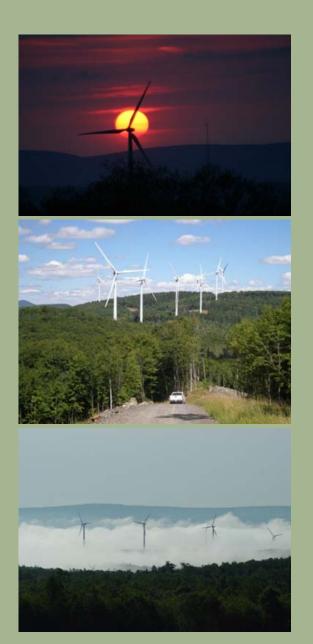


Installed capacity in Canada and the U.S.



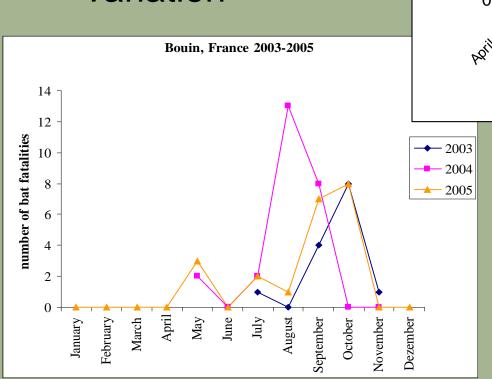
Patterns associated with fatalities

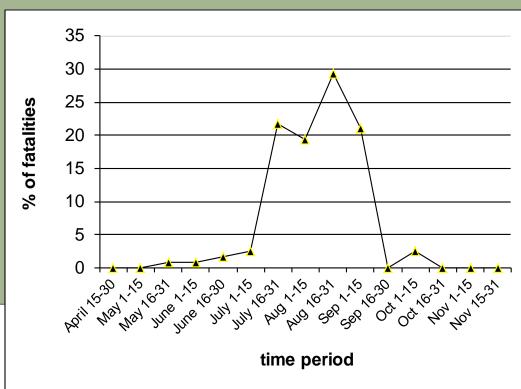
- Temporal
- Spatial
- Habitat relationships
- Weather and environmental variables



Temporal patterns

- Fatalities peak in autumn, in both N.A. and Europe
- Year-to-year variation





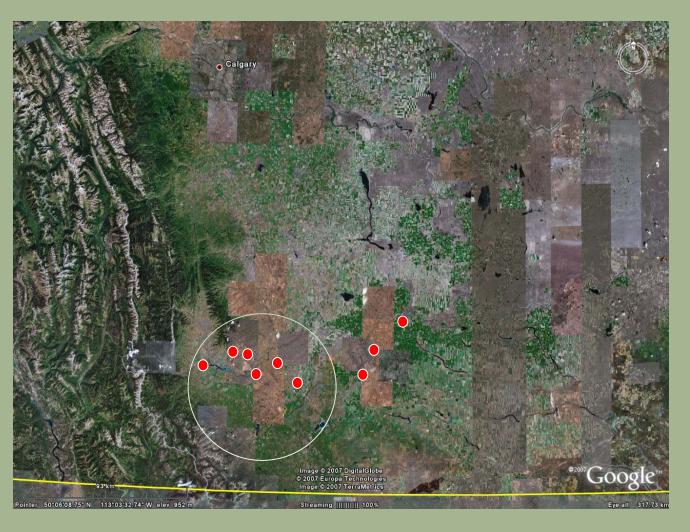
Spatial Patterns: site specific

- Fatalities are distributed among turbines at facilities (i.e. tends not to be a "killer turbine"
- Turbines in the North end of a facility may have higher fatality rates (Baerwald and Barclay 2011)



Spatial Patterns: landscape level

Facilities closer to Eastern slopes of the Rocky Mountains had higher activity and fatalities relative to those further east (Baerwald and Barclay 2009)



Bat fatalities have been found worldwide in many habitat conditions



Habitat Relationships

Studies have not yet identified <u>consistent</u> relationships with habitat variables (e.g., distance to water, wetlands, or forest edge)

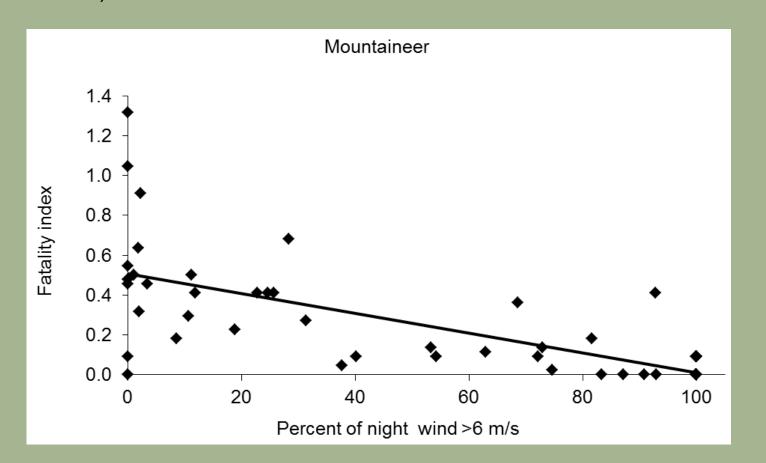




Weather and environmental factors

Bat fatalities are higher in low wind speeds

(Arnett et al. 2008, Rydell et al. 2010, Young et al 2010, 2011, Jain et al. 2011, Good et al. 2011)

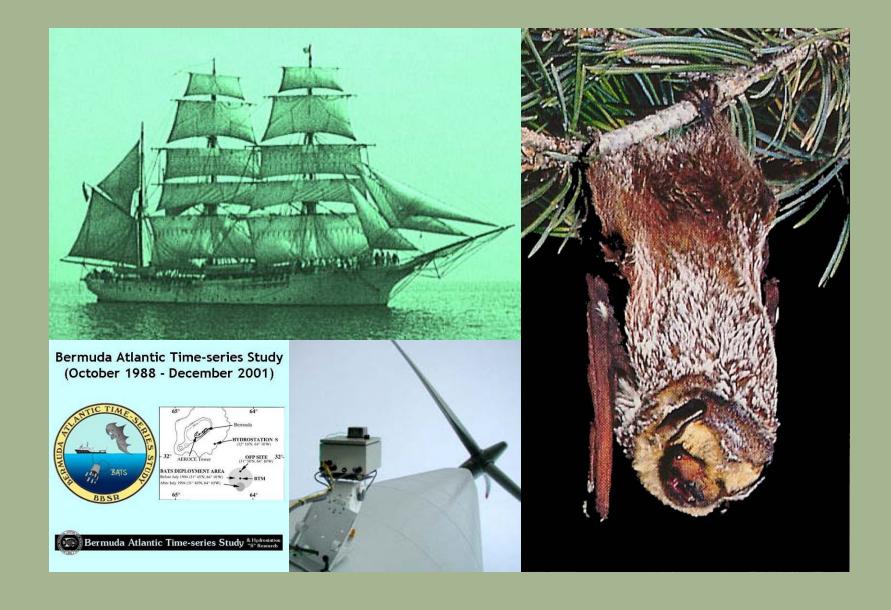


Weather and environmental factors



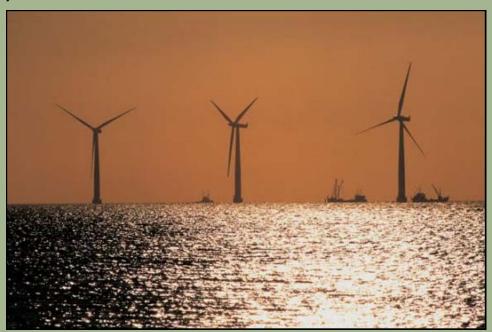
- Bat fatalities associated with
 - Temperature (+)
 - Precipitation/relative humidity (-)
 - Barometric pressure
 - Moon illumination
 - Bat activity

Offshore/Near-shore Wind and Bats



Bat activity offshore/near-shore

- Bats follow coastlines in autumn and appear to concentrate at certain points before migrating or foraging out at sea (11 spp. found out at sea) (Ahlen et al 2009)
- Bats observed roosting on nacelles off-shore (Ahlen et al 2009)



Bat activity offshore/near-shore U.S.

- Six species detected off shore: hoary bat, eastern red, silver-haired, tri-colored, big brown, Myotis spp. (Johnson et al 2011, Sjollema et al 2014)
- Up to 22 km from shore (Sjollema et al 2014)
- Associated with migratory periods and weather

• Increased activity in low wind speeds (Johnson et al 2011, Sjollema et al 2014) and higher temperatures (Johnson et al

2011)









- Offshore issues may have some similarities with those onshore, but they are different ecologically and only some of the information from on-shore impacts may be transferable to offshore facilities
- Pre-construction assessments are critical, as postconstruction monitoring of fatalities offshore is seemingly hopeless



Will raising turbine cut-in speed reduce fatality of bats?

- Cut-in speed is the lowest wind speed at which turbine generated electricity enters the power grid
- Manufacturer's cut-in for modern turbines is 3.5-4.0 m/s (~8-9 mph)

 Raise cut-in for each turbine, and blades remain "feathered" (i.e., pitched OUT or parallel with the wind)...free-wheel, but move VERY slowly



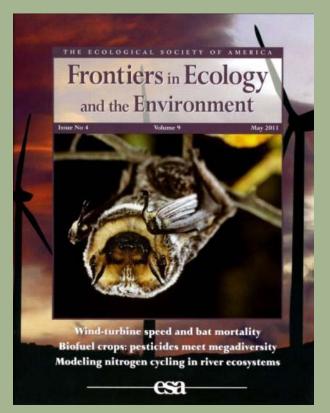
Supporting evidence

- Bats do not frequently strike stationary objects (Horn et al. 2008)
- Large percentage of kills occur on low wind nights when energy production is marginal (Arnett et al. 2008, Rydell et al. 2010)
- Higher activity of bats during low wind periods, generally <6 m/s when energy production is marginal (Arnett et al. 2006, Reynolds 2006, Horn et al. 2008, Baerwald and Barclay 2011, Weller and Baldwin 2012)

Curtailment Studies:

Study conducted in Alberta Canada in 2006-07 found ~60% reduction in kills with 5.5 m/s cut-in

(Baerwald et al. 2009)





In 2008-09, 44–93% fewer bats killed at turbines with cut-in speed raised between 5.0-6.5 m/s

0.3- ~1% annual power loss with cut-in speed raised between 5.0-6.5 m/s

(Arnett et al. 2011)

Curtailment Studies:



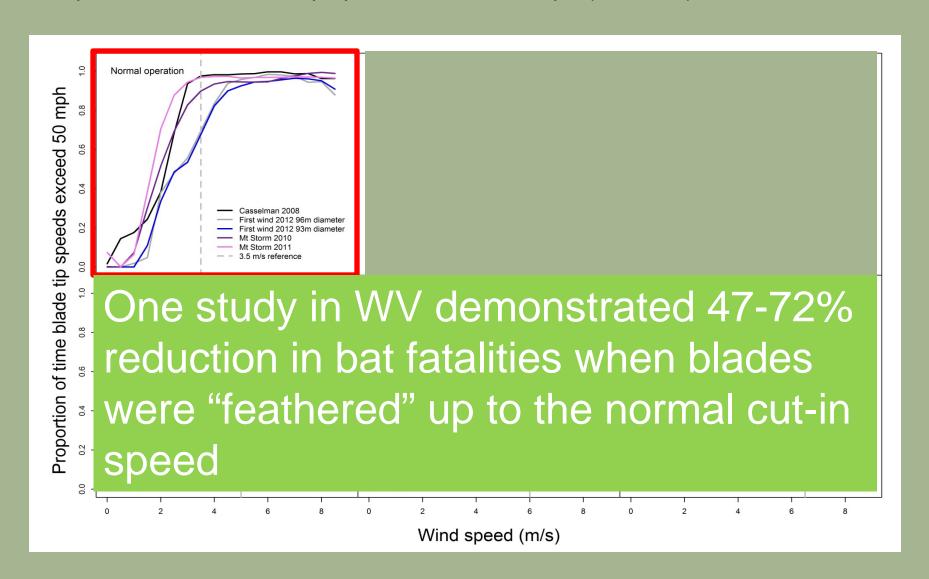
Fowler Ridge, IN - <u>50% and 78%</u> reduction in bat fatality at 5.0 and 6.5 m/s, respectively (Good et al. 2011)

Fowler Ridge, IN - <u>36%</u>, <u>57%</u>, and <u>73%</u> reductions in bat fatalities at 3.5, 4.5 and 5.5 m/s, respectively (Good et al. 2012)

Mount Storm, WV - <u>72% and 23%</u> reductions in bat fatalities for 1st 4 hrs after sunset and last 4 hrs before sunrise, respectively at 4.0 m/s ("normal" cut-in speed) (Young et al. 2010)

Low Hanging Fruit? (from Arnett et al. submitted)

Proportion of time blade tip speeds exceed 50 mph (22.4 m/s)







Acoustic Deterrents

- 21–51% fewer fatalities at treatment turbines in 2009
- ~2% more to 64% fewer bats killed at treatment turbines in 2010 (Arnett et al. 2013)





CHALLENGE: Coverage & attenuation!

- Expensive to get "full" coverage
- Ultrasound attenuates very quickly

Caution!

- We currently <u>DO NOT</u> have a functional device that can be deployed at operating wind facilities
- More R&D and field experimentation required and is underway
- Engineers continue designing new prototypes based on previous devices and data...

Where to Next?

Evidence supports that bat fatalities can be mitigated

- Continue "fine-tuning" curtailment
- IMPLEMENT BROADLY at sites with moderate - high kills
- Further develop and test deterrent devices and determine their biological and <u>cost</u> <u>effectiveness</u>

Continue studies to determine high risk sites that should be avoided.





Some Priority Questions Need Answering Sooner than Later...

Siting Guidance



Activity and Fatality Patterns
Migratory Patterns
Stop-over Sites

Population Impact

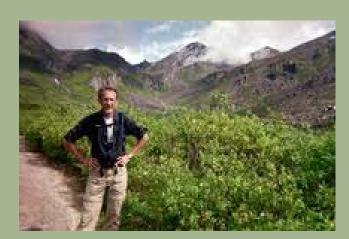


Context of Fatalities
Population Levels
Cumulative Impacts





Dedicated to our Friends



Andy Linehan



David Redell



Dr. Tom Kunz

