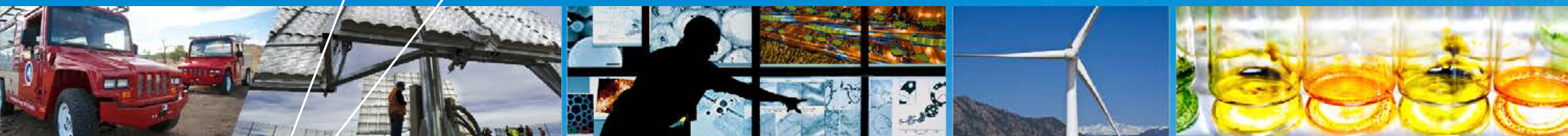
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Environmental Lessons Learned from Terrestrial Wind Experience

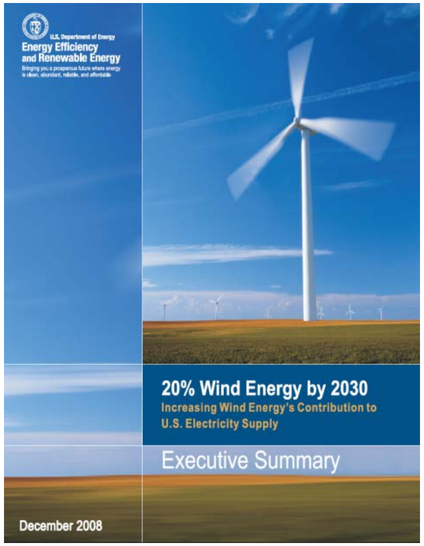


Bob Thresher, PhD
NREL Research Fellow

Sacramento, California
August 30, 2014

The Terrestrial Wind Energy Siting and Permitting Challenge

To reach 20% wind energy by 2030 will require minimizing the barriers to siting and permitting by "understanding, minimizing and, mitigating environmental impacts to wildlife". The issues that must be addressed through further research are:



- **Understanding, avoiding, minimizing and mitigating specific species impacts:**
  - Birds
  - Bats
  - Other species using the windfarm habitat
- **Habitat modification and fragmentation effects**
- **Individual animal versus cumulative population impacts**
- **The influence of variables such as weather, lighting, turbine height, turbine rotation speed**
- **Effective mitigation measures and methods, both onsite and offsite**

Perhaps the Offshore siting challenges will be quite similar?

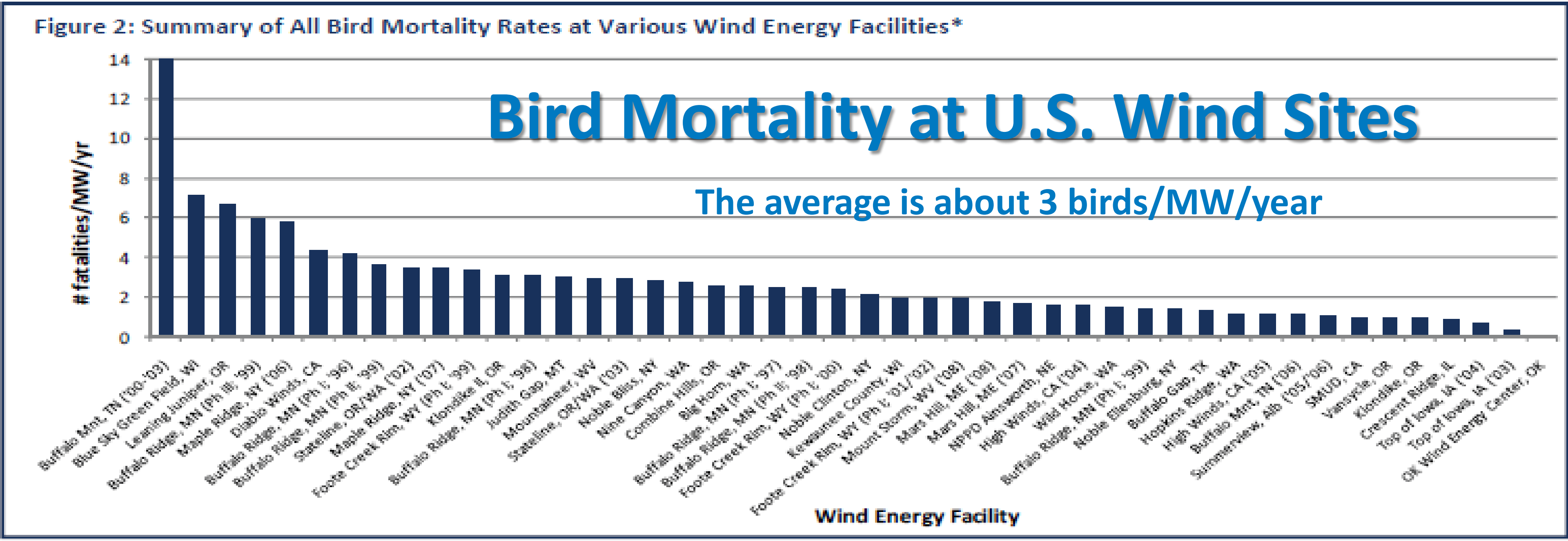


Figure 2: Summary of All Bird Mortality Rates at Various Wind Energy Facilities*
Bird Mortality at U.S. Wind Sites
The average is about 3 birds/MW/year
fatalities/MW/yr
14
12
10
8
6
4
2
0
Buffalo Mnt, TN ('00-'03)
Blue Sky Green Field, WI
Leaning Juniper, OR
Buffalo Ridge, MN (Ph II; '99)
Maple Ridge, NY ('06)
Diablo Winds, CA
Buffalo Ridge, MN (Ph I; '96)
Buffalo Ridge, MN (Ph III; '99)
Stateline, OR/WA ('02)
Maple Ridge, NY ('07)
Foote Creek Rim, WY (Ph I; '99)
Klondike II, OR
Buffalo Ridge, MN (Ph I; '98)
Judith Gap, MT
Mountaineer, WV
Stateline, OR/WA ('03)
Noble Bliss, NY
Nine Canyon, WA
Combine Hills, OR
Big Horn, WA
Buffalo Ridge, MN (Ph I; '97)
Buffalo Ridge, MN (Ph II; '96)
Foote Creek Rim, WY (Ph I; '00)
Noble Clinton, NY
Kewaunee County, WI
Foote Creek Rim, WY (Ph I; '01/'02)
Mount Storm, WV ('08)
Mars Hill, ME ('08)
Mars Hill, ME ('07)
NPPD Ainsworth, NE
High Winds, CA ('04)
Wild Horse, WA
Buffalo Ridge, MN (Ph I; '99)
Noble Ellenburg, NY
Buffalo Gap, TX
Hopkins Ridge, WA
High Winds, CA ('05)
Buffalo Mnt, TN ('06)
Summerview, Alb ('05/'06)
SMUD, CA
Vansycle, OR
Klondike, OR
Crescent Ridge, IL
Top of Iowa, IA ('04)
Top of Iowa, IA ('03)
OK Wind Energy Center, OK
Wind Energy Facility

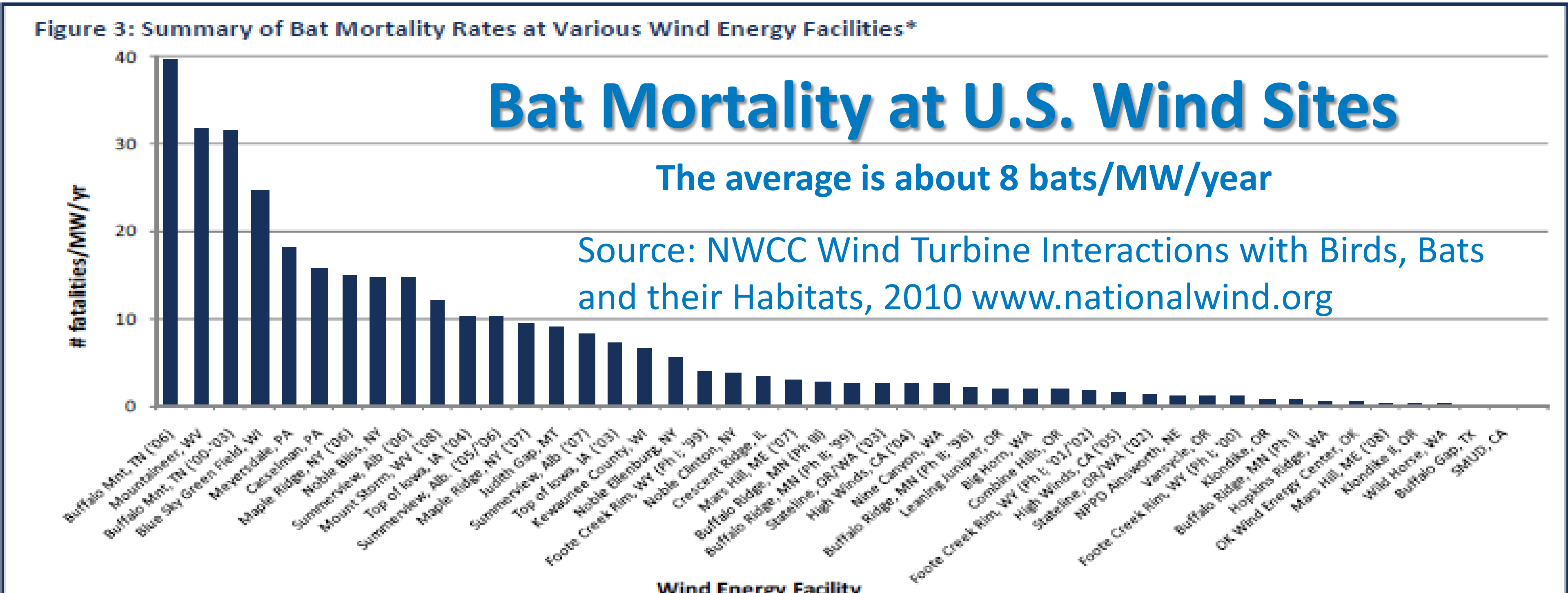


Figure 3: Summary of Bat Mortality Rates at Various Wind Energy Facilities*
Bat Mortality at U.S. Wind Sites
The average is about 8 bats/MW/year
Source: NWCC Wind Turbine Interactions with Birds, Bats and their Habitats, 2010 www.nationalwind.org
fatalities/MW/yr
40
30
20
10
0
Buffalo Mnt, TN ('06)
Mountaineer, WV
Buffalo Mnt, TN ('00-'03)
Blue Sky Green Field, WI
Meyersdale, PA
Casselman, PA
Maple Ridge, NY ('06)
Noble Bliss, NY
Summerview, Alb ('06)
Mount Storm, WV ('08)
Top of Iowa, IA ('04)
Summerview, Alb. ('05/'06)
Maple Ridge, NY ('07)
Judith Gap, MT
Summerview, Alb ('07)
Top of Iowa, IA ('03)
Kewaunee County, WI
Noble Ellenburg, NY
Foote Creek Rim, WY (Ph I; '99)
Noble Clinton, NY
Crescent Ridge, IL
Mars Hill, ME ('07)
Buffalo Ridge, MN (Ph III)
Buffalo Ridge, MN (Ph II; '99)
Stateline, OR/WA ('03)
High Winds, CA ('04)
Nine Canyon, WA
Buffalo Ridge, MN (Ph II; '98)
Leaning Juniper, OR
Big Horn, WA
Combine Hills, OR
Foote Creek Rim, WY (Ph I; '01/'02)
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Buffalo Ridge, MN (Ph I)
Hopkins Ridge, WA
OK Wind Energy Center, OK
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Buffalo Gap, TX
SMUD, CA
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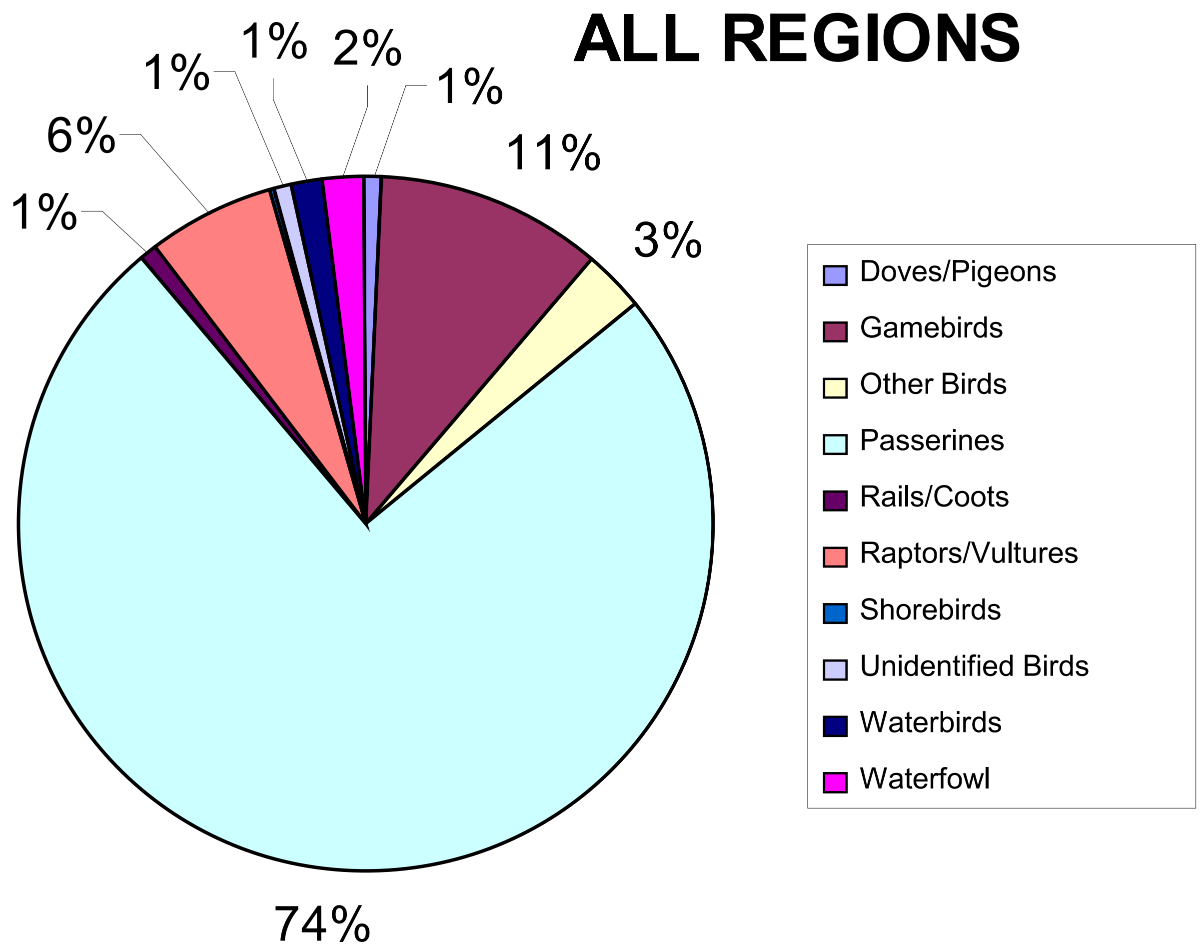
Wind and Wildlife: Wind Turbine Bird Fatalities

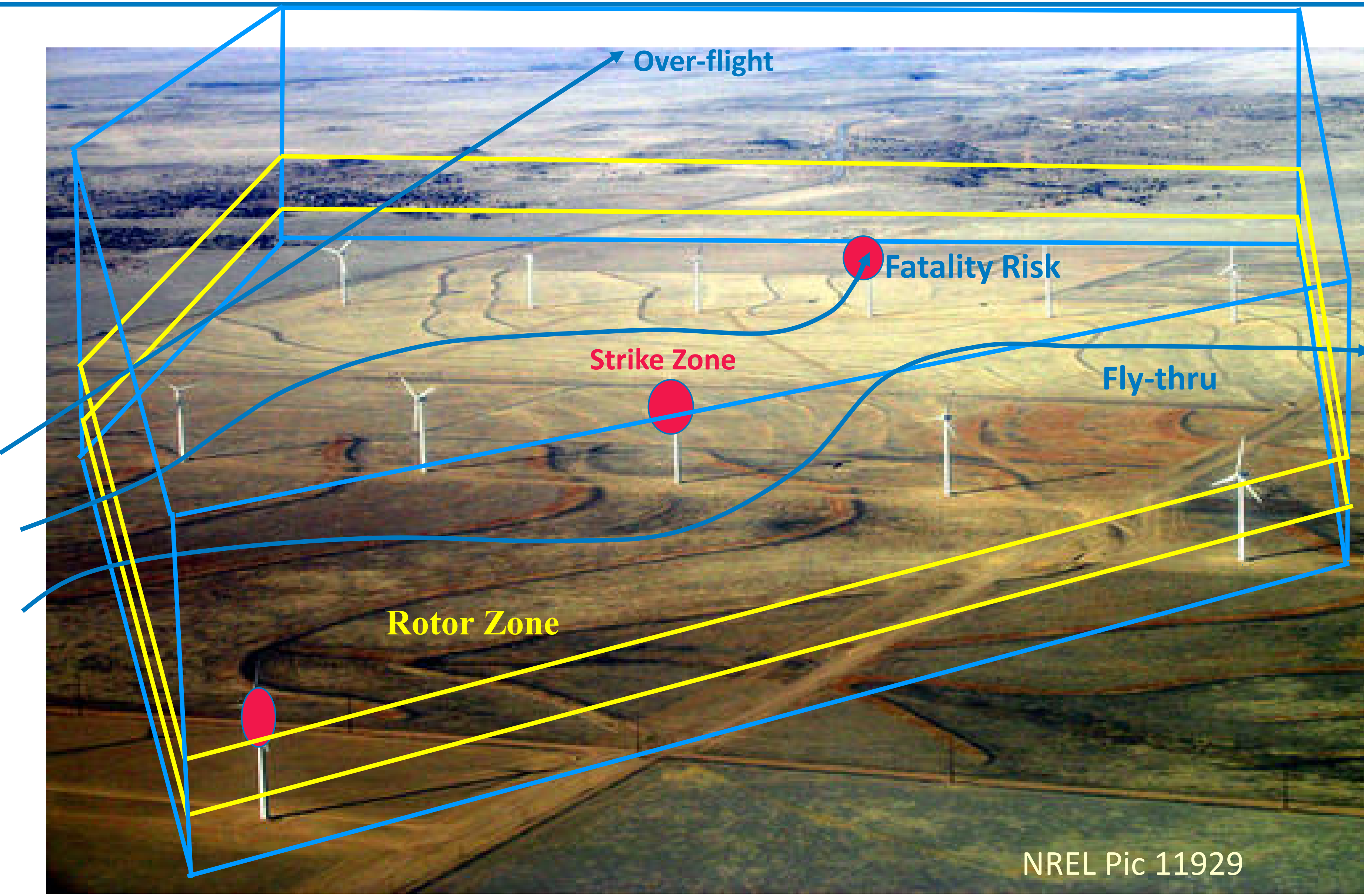


Proportion of fatalities at sites reporting fatalities by species, summarized for all regions where studies have been conducted (Pacific Northwest, Mid-West, Rocky Mountains, and East).

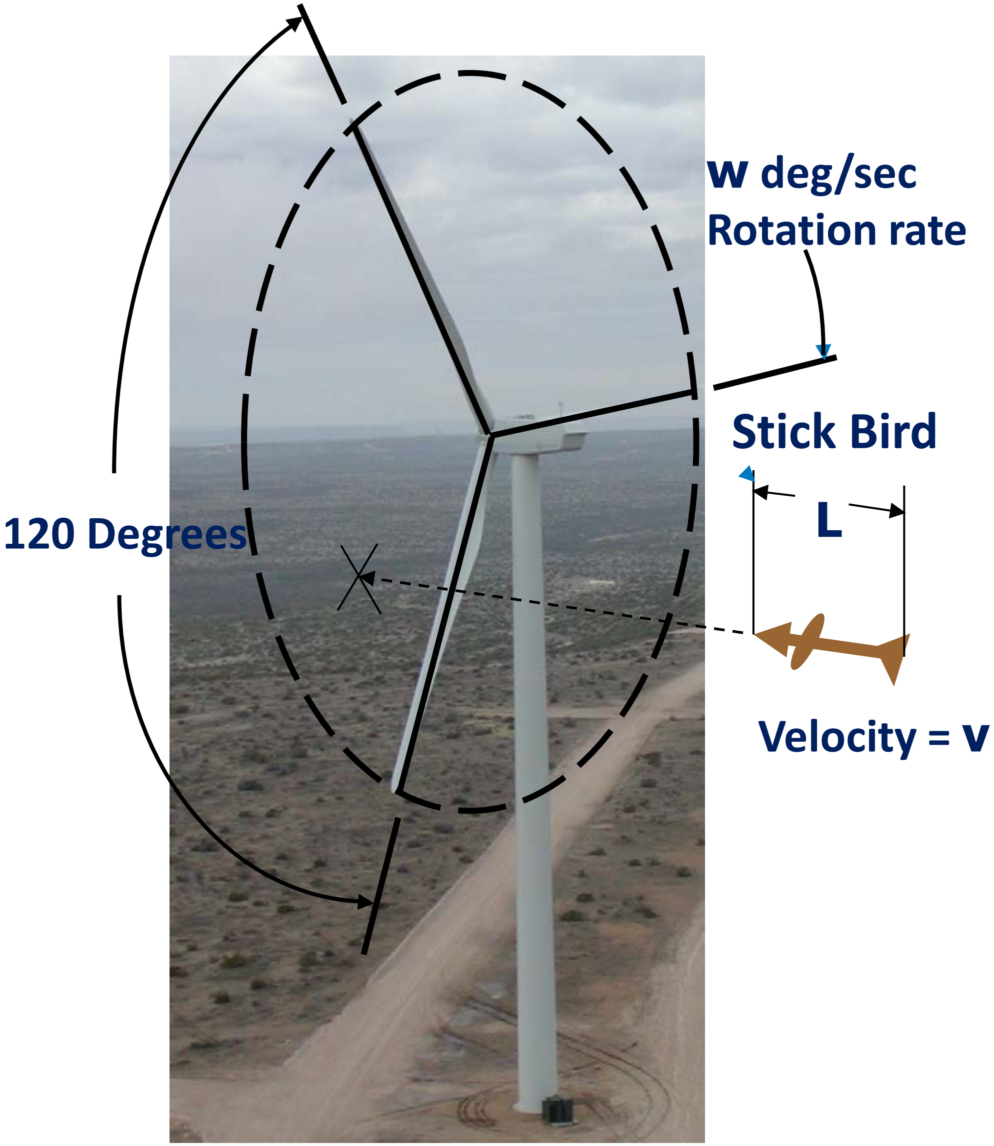
Source: https://www.nationalwind.org/assets/research_meetings/Research_Meeting_VII_Erickson.pdf Erickson, Strickland, Young, Johnson, Western EcoSystems Technology, Inc.

Visualization of Avian Interaction Zones

Windfarm Flight Zone



Avian Impact Probability: Stick Collision Model



Stick Turbine

Bird passage time through the rotor:

t_p=L/V= Length speed ratio (sec)

Blocked Sector of Turbine Rotor:

B =t_pw (deg)

Probability of collision:

P_c =Blocked Area/Disk Area

P_c =3B/(360deg**)**

P_c =3(L/V){w(deg/sec**)/360**deg**}**

To account for avoidance add a factor A :

P_c =3 A (L/V){w(deg/sec**)/360**deg**}**

where A = { **<1 for avoidance**, **1 for no behavior**, **>1 for attraction** }

Avian Strike Probability Versus Turbine Size

Altamont Scale

15 Meter Diameter and 100 kW
PhotoCredit: Robert Thresher, NREL

Next Generation Scale

Clipper 2.5MW wind turbine.
93 Meter Diameter
Photo Credit: Alan Laxson, NREL

Candidate Avian Risk Metrics

Hypothesis: "Mortality risk increases with flight time in the rotor zone (yellow zone), if the turbine is operating"

- **A Candidate Post-construction Fatality Metric:**

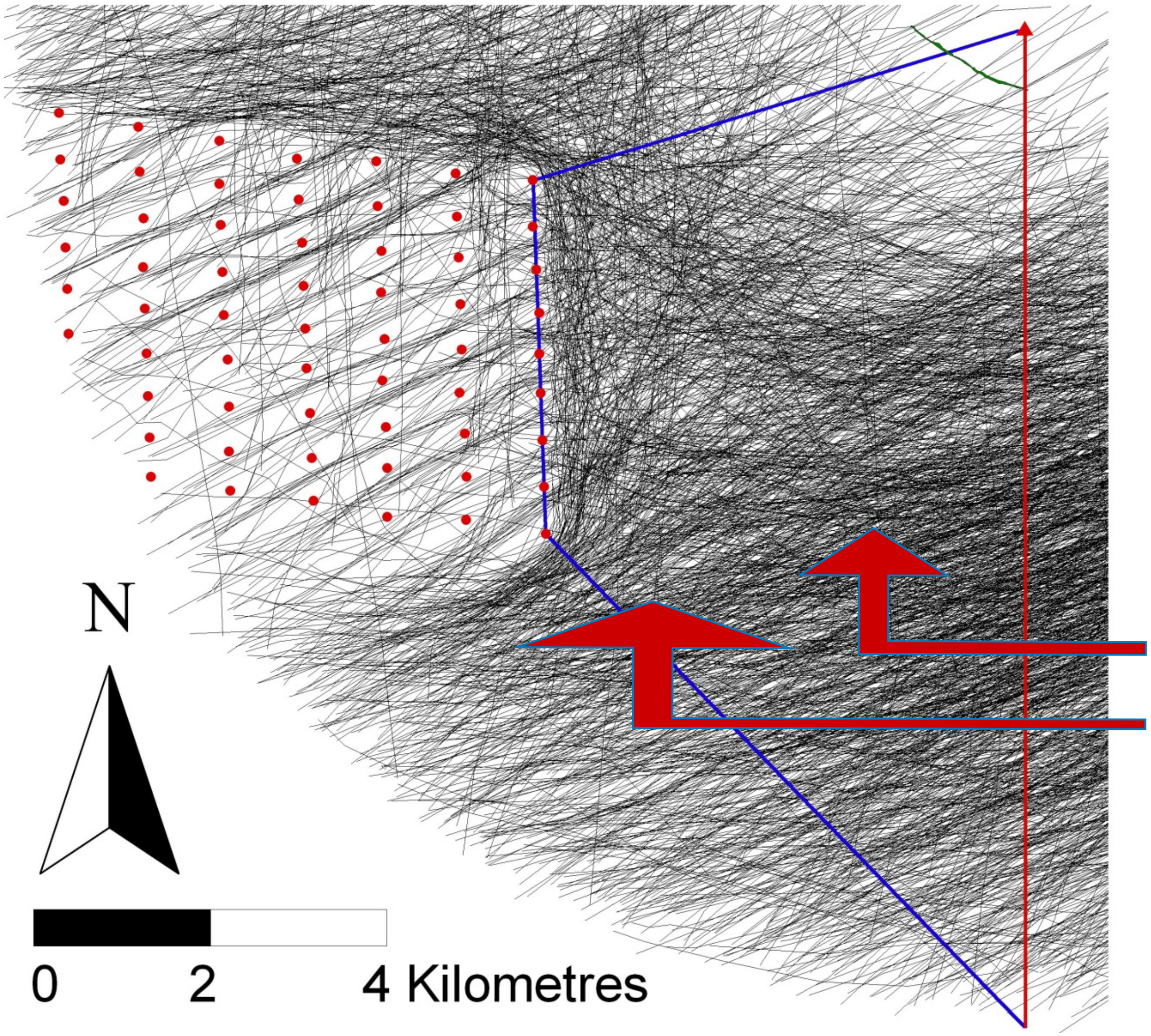
  Species Risk = Fatalities/(Swept Area x Turbine Operation Hours)

- **A Candidate Preconstruction Relative Risk Metric:**

  Species Relative Risk = (Flight Hours in Rotor Zone with Wind in Operating Range)/(Plant Swept Area x Hours with Wind in Operating Range)

Avoidance Behavior is Significant

Radar Tracks of Migrating Birds through Nysted Offshore Windfarm for Operation in 2003



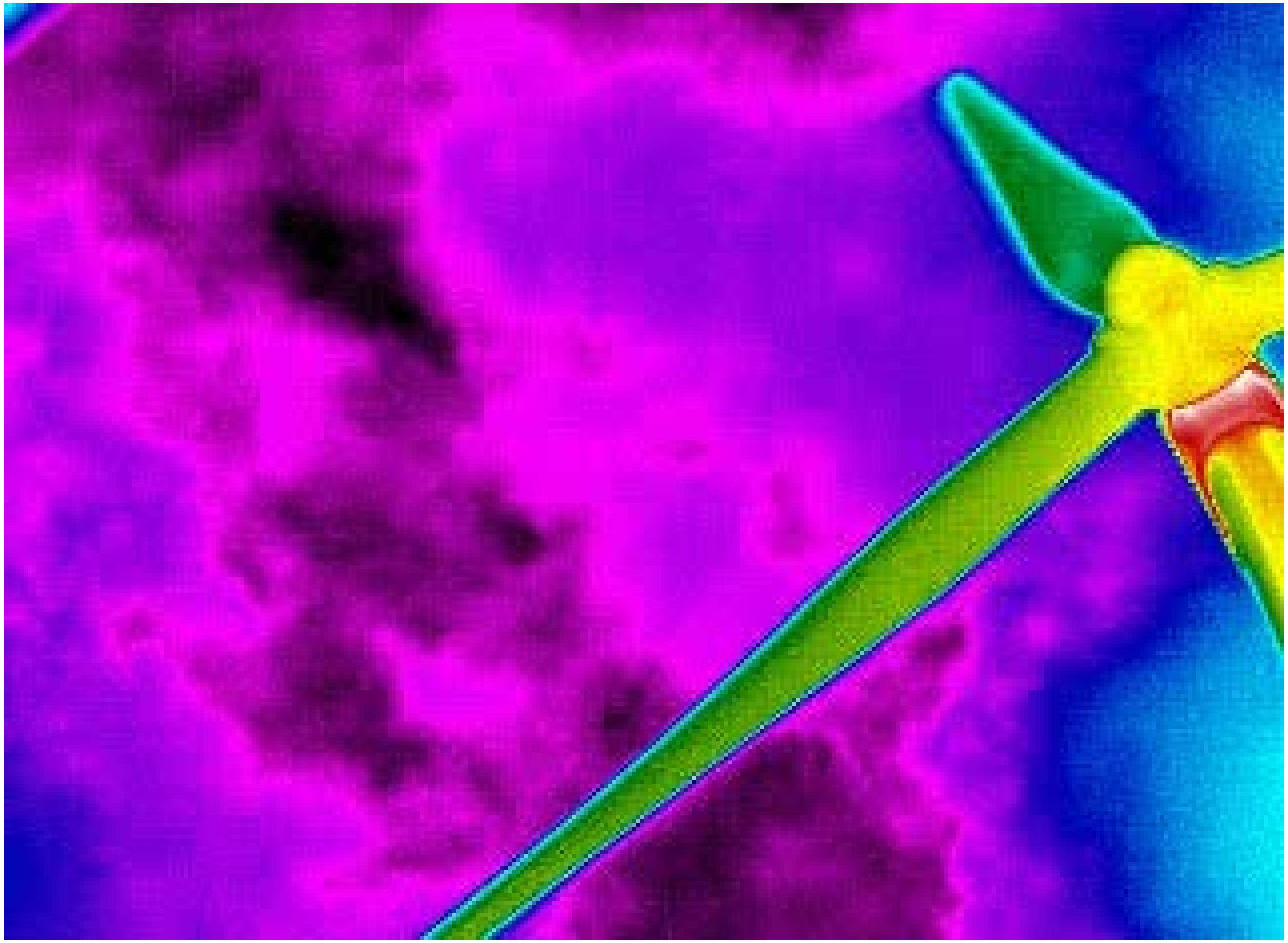
Source: The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farm. Environmental Impact Assessment and Monitoring. Review Report 2003.

Response distance:

day = c. 3000m

night = c. 1000m

Bats and Wind Energy Cooperative Studies

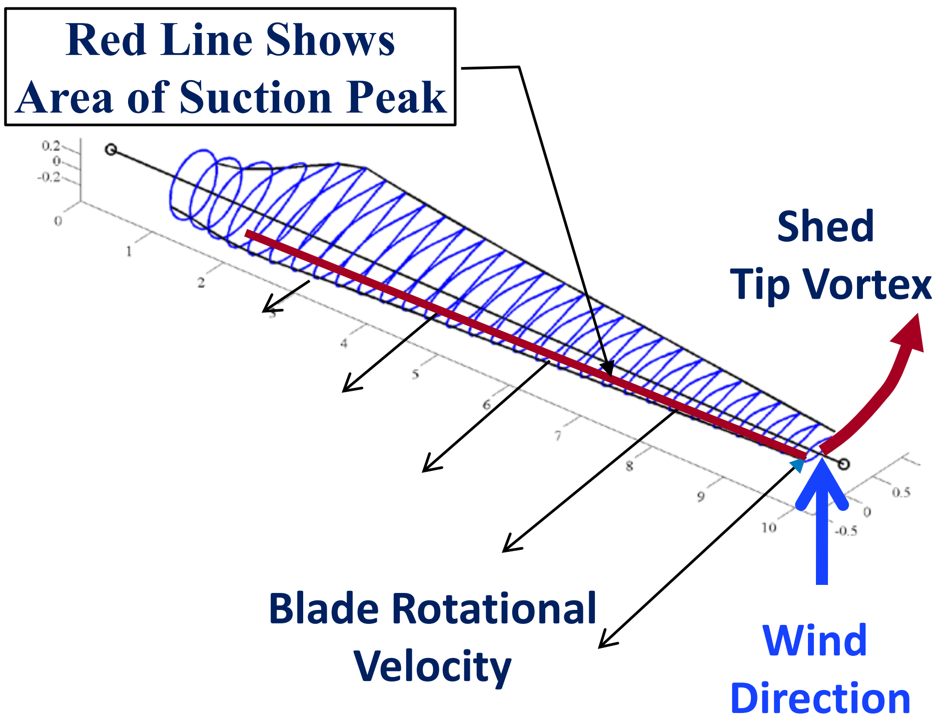


Infrared Image of a Bat Flying Through a Wind Turbine Rotor

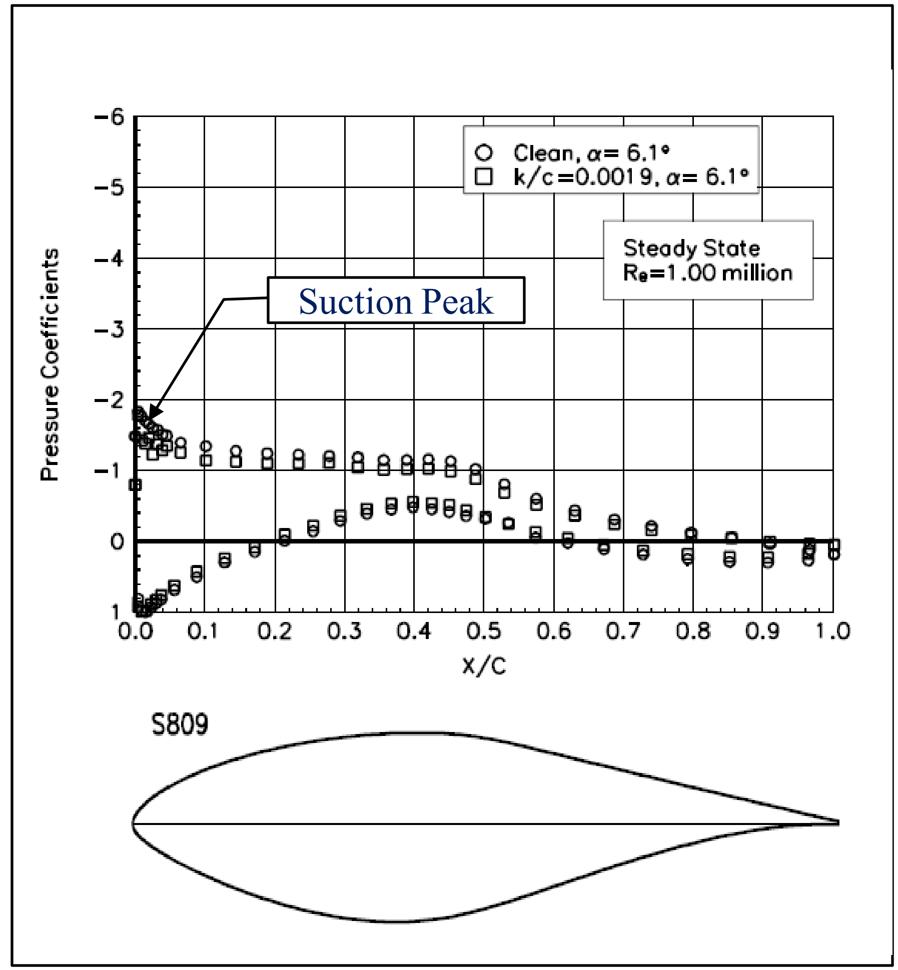
Source: J. Horn, E. Arnett, T. Kunz. Behavioral Responses to Bats at Operating Wind Turbines. Journal of Wildlife Management 72(1):123-132; 2008
Video by Jason Horn, Boston University

Bat Barotrauma (hypothesis) - Low Pressure Trauma:

Do the low pressure areas near wind turbine blades kill bats?

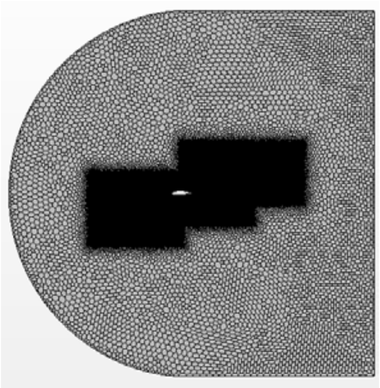


Airfoils Suction Peak Location

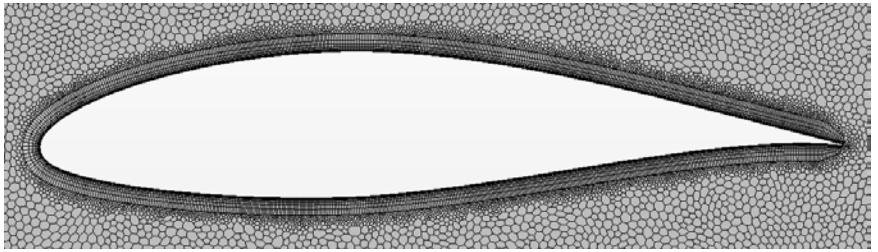


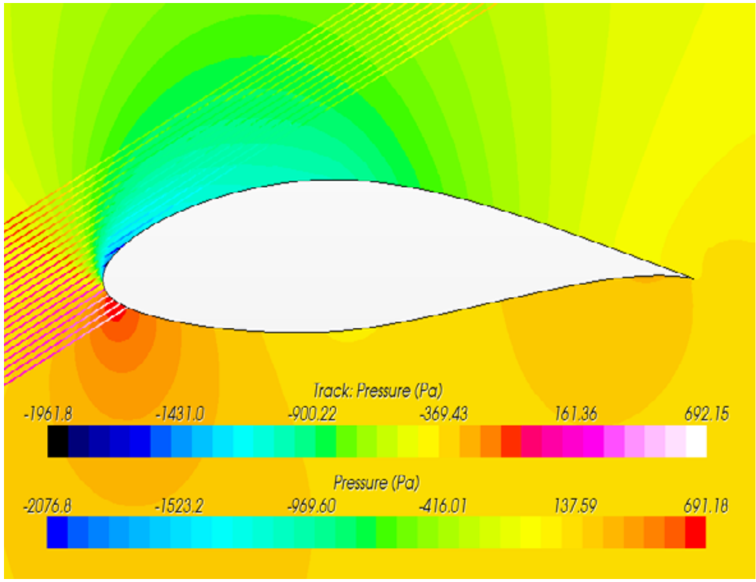
The Pressure Distribution on an Airfoil

Preliminary results from a 2-D CFD simulation of a bat flying through a wind turbine rotor

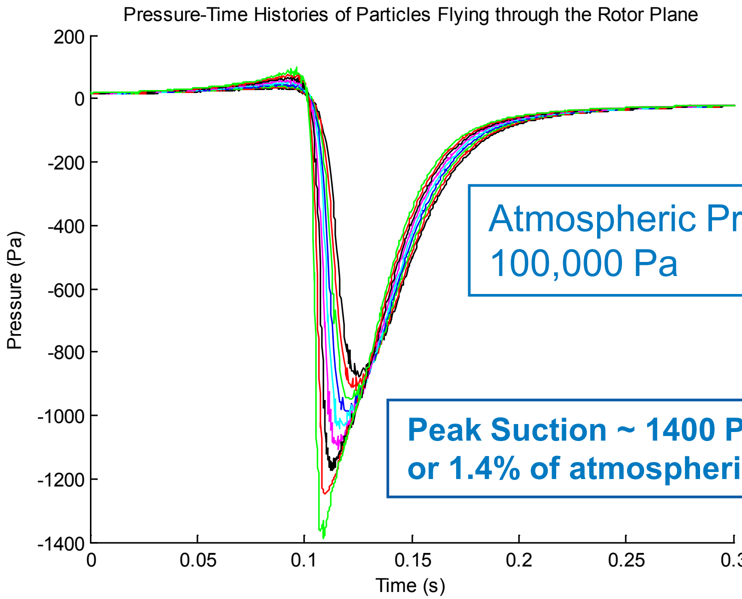


On left, c-shaped mesh with refined mesh for inflow and wake regions and, on right, refined mesh around the airfoil





Pressure field and Lagrangian particle tracks representing possible bat flight paths.



Conclusion: Barotrauma probably not a significant contributor to bat fatalities.

Source: Houck, Lawson & Thresher NREL Internal Project

http://nationalwind.org/research/meetings/research-meeting-ix/

Some Operational Mitigation Study Results

Hypothesis: Increasing the turbine start-up wind speed (when the rotor turns) should reduce bat fatalities, because most bat species don't like to fly at wind speeds above about 6 m/s. The Table below shows some study results:

Study Area Location	Study Area Acronym	Mean Fatality Reduction (%)	Lost production	Literature Citation
Canada				
Summerview, Alberta	SVAB	57% (4.0 m/s), 60% (5.5 m/s)	~$3,000-4,000 Canadian, but turbines were curtailed 24 hours and only projected for study period	Baerwald 2008; Baerwald et al. 2009
Wolfe Island, Ontario	WIWF	60% (5.5 m/s) 4.8 (4.5 m/s)	n/a	Stantec Consulting, Ltd. 2012
United States				
Cassleman, Pennsylvania	CWPP	2008: 82% 2009: 72%	0.3% (5.0 m/s) 1% (6.5 m/s)	Arnett et al. 2010; Arnett et al. 2011
Fowler Ridge, Indiana	FRWF	2010: 50% (5.0 m/s) 78% (6.5 m/s)	n/a	Good et al. 2010, 2011
		2011 Feathering below 3.5–36.3%, below 4.5–56.7%, below 5.5–73.3	n/a	

Source: Ed Arnett, et al, "A SYNTHESIS OF OPERATIONAL MITIGATION STUDIES TO REDUCE BAT FATALITIES AT WIND ENERGY FACILITIES IN NORTH AMERICA " BWEC Report, March 2013. http://www.batsandwind.org/

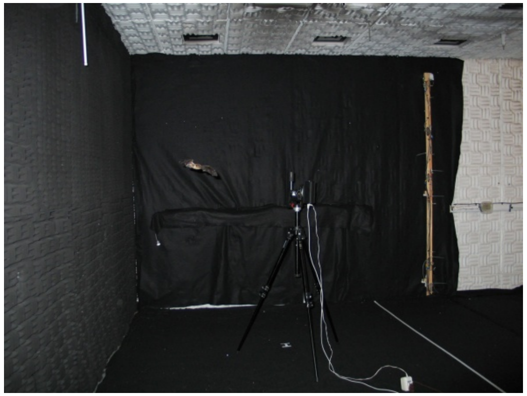
Bat Deterrent possibility:

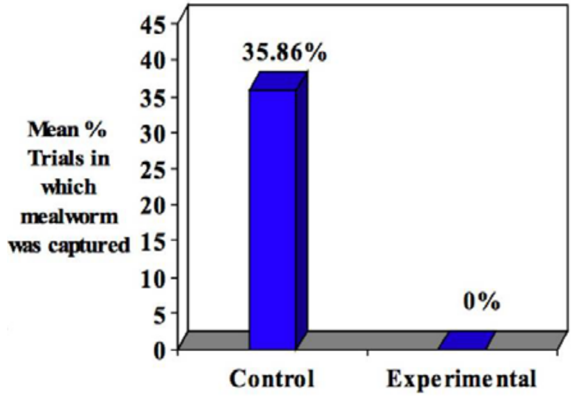
Can we generate a disorienting or uncomfortable airspace around turbines that will deter bats?

NREL/PIX 21206

Lab Test Findings and unit evolution:

- In the lab: captive bats unable to catch prey with device active





- At ponds in the field: ~90% reduction within 12m of device
- Sustained effect at ponds, i.e., no indication of habituation

Source: Spanjer, G. R. 2006. Responses of the big brown bat, *Eptesicus fuscus, to a proposed acoustic deterrent device in a lab setting. A report submitted to the Bats and Wind Energy Cooperative and the Maryland Department of Natural Resources. Bat Conservation International. Austin, Texas, USA.*

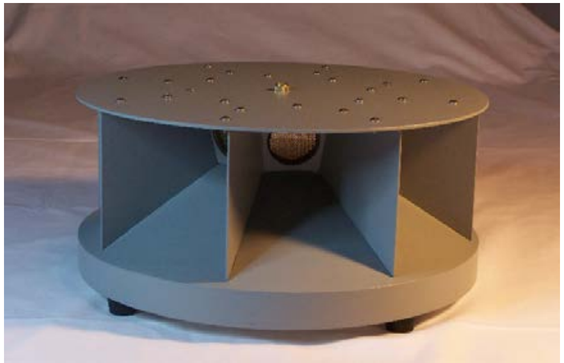


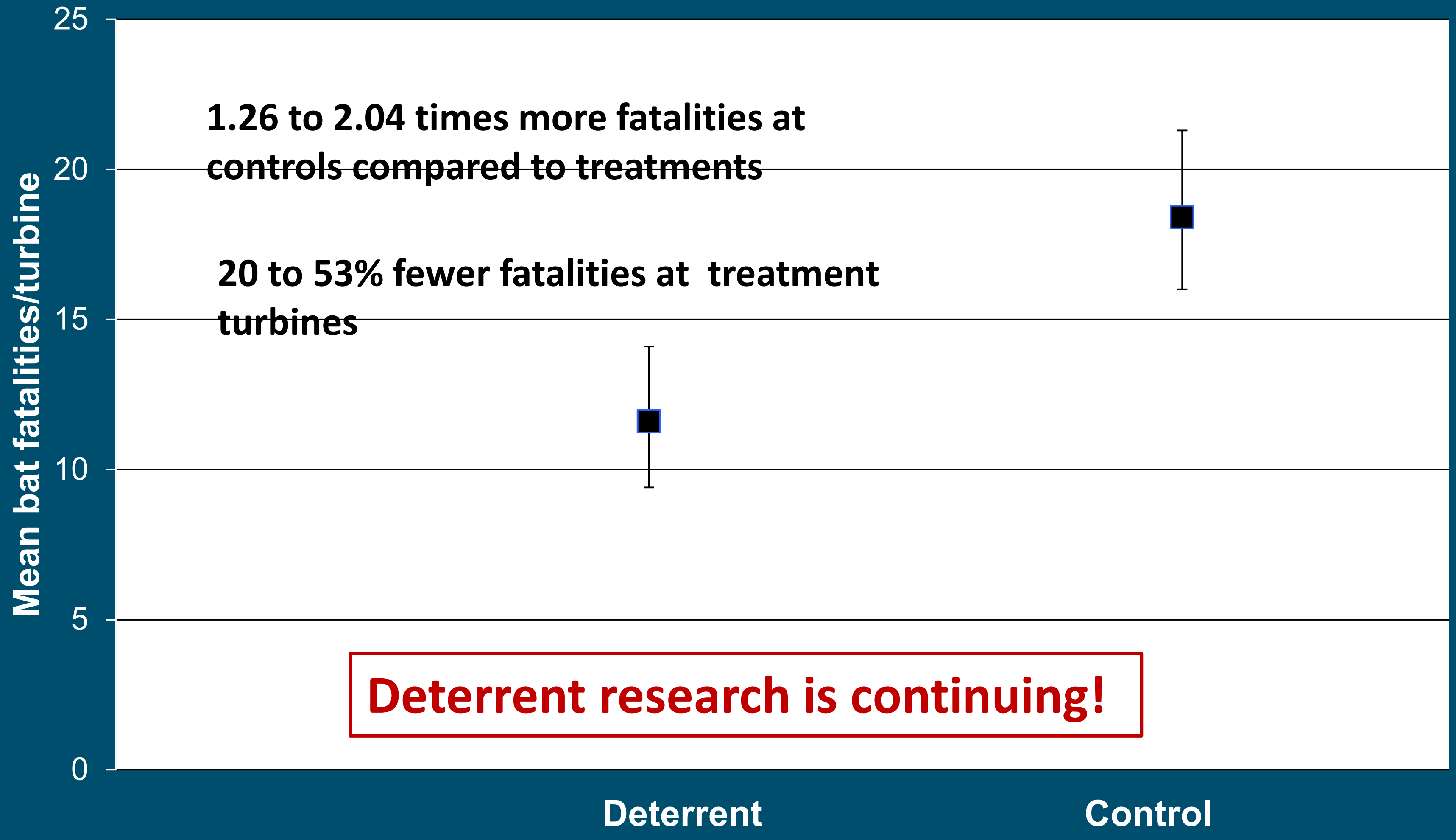
Photo Top Left from Rebecca Patterson, Bat Conservation International, Bottom Left photo from Mark Jensen, Binary Acoustic Technology, Bottom Right photo Joseph M. Szewczak, Humboldt

Field testing at Iberdrola's Locust Ridge Facility

PA, Summer 2009

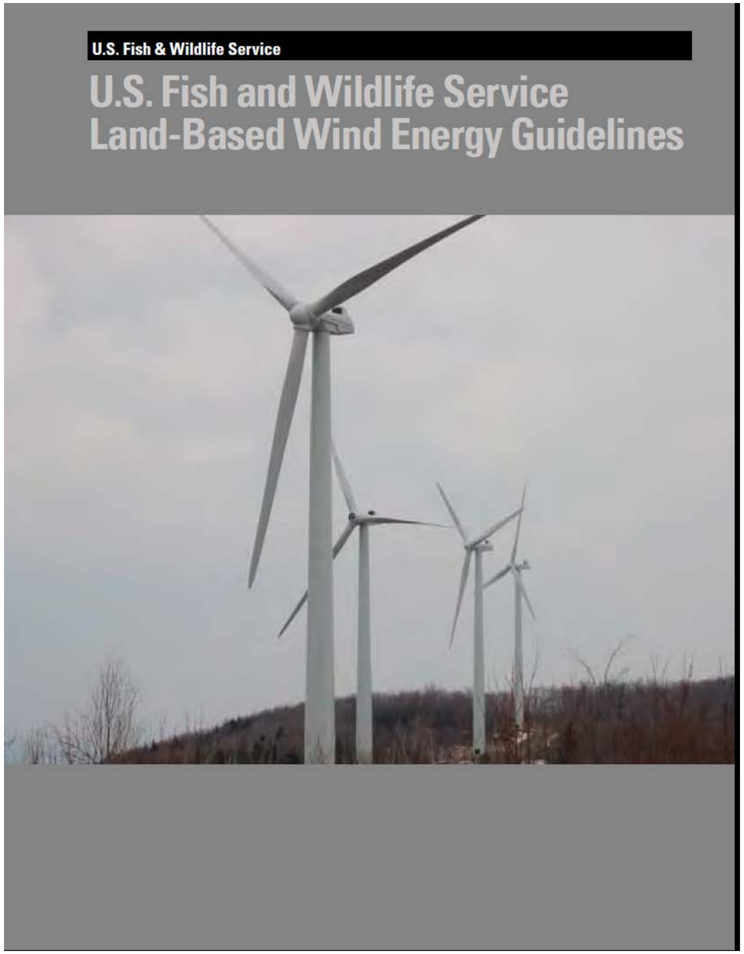
Photo source: BWEC

Sample of Deterrent Results from 2009



Source : Arnett EB, Hein CD, Schirmacher MR, Huso MMP, Szewczak JM (2013) Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent for Reducing Bat Fatalities at Wind Turbines. PLoS ONE 8(6): e65794. doi:10.1371/journal.pone.0065794

The USFWS Terrestrial Wind Energy Wildlife Guidelines: The Results of Federal Advisory Committee Collaboration



Released March 2012

A Tiered Approach :

- Tier 1 – Preliminary site evaluation (landscape-scale screening of possible project sites)
- Tier 2 – Site characterization (broad characterization of one or more potential project sites)
- Tier 3 – Field studies to document site wildlife and habitat and predict project impacts
- Tier 4 – Post-construction studies to estimate impacts
- Tier 5 – Other post-construction studies and research

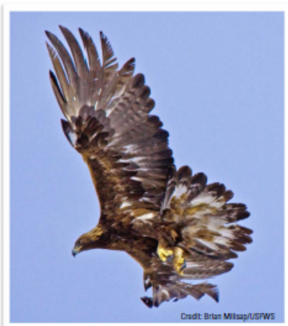
USFWS Eagle Guidance

U.S. Fish and Wildlife Service

Eagle Conservation Plan Guidance

Module 1 – Land-based Wind Energy

Version 2



U.S. Fish and Wildlife Service
Division of Migratory Bird Management

April 2013

EXECUTIVE SUMMARY

1. Overview

Of all America's wildlife, eagles hold perhaps the most revered place in our national history and culture. The United States has long imposed special protections for its bald and golden eagle populations. Now, as the nation seeks to increase its production of domestic energy, wind energy developers and wildlife agencies have recognized a need for specific guidance to help make wind energy facilities compatible with eagle conservation and the laws and regulations that protect eagles.

To meet this need, the U.S. Fish and Wildlife Service (Service) has developed the Eagle Conservation Plan Guidance (ECPG). This document provides specific in-depth guidance for conserving bald and golden eagles in the course of siting, constructing, and operating wind energy facilities. The ECPG guidance supplements the Service's Land-Based Wind Energy Guidelines (WEG). WEG provides a broad overview of wildlife considerations for siting and operating wind energy facilities, but does not address the in-depth guidance needed for the specific legal protections afforded to bald and golden eagles. The ECPG fills this gap.

Like the WEG, the ECPG calls for wind project developers to take a staged approach to siting new projects. Both call for preliminary landscape-level assessments to assess potential wildlife interactions and proceed to site-specific surveys and risk assessments prior to construction. They also call for monitoring project operations and reporting eagle fatalities to the Service and state and tribal wildlife agencies.

Compliance with the ECPG is voluntary, but the Service believes that following the guidance will help project operators in complying with regulatory requirements and avoiding the unintentional "take" of eagles at wind energy facilities, and will also assist the wind energy industry in providing the biological data needed to support permit applications for facilities that may pose a risk to eagles.

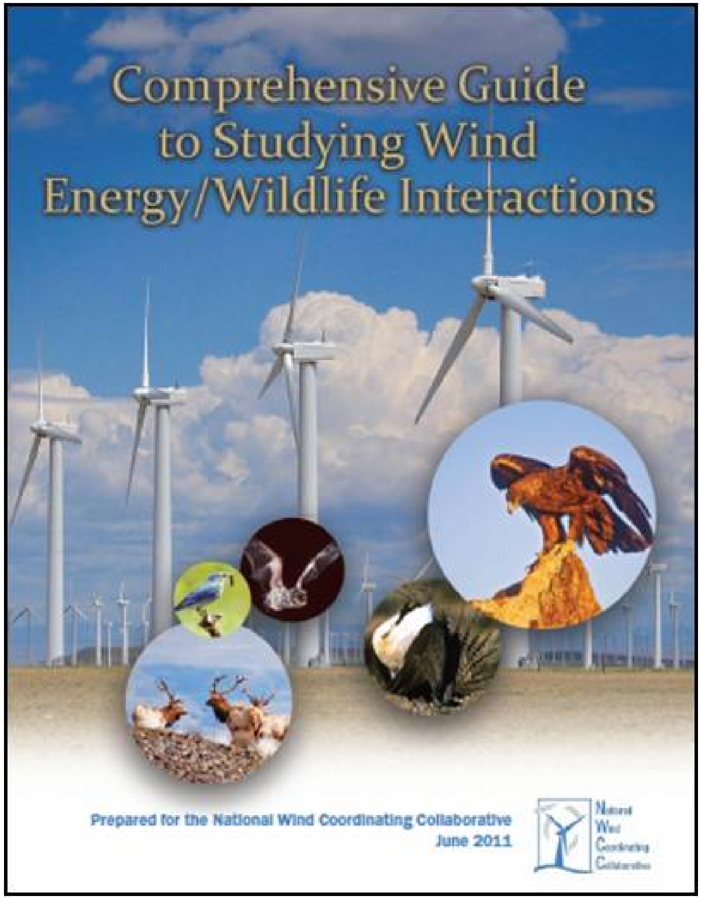
Key Point: An incidental take permit is required of wind facilities under this Guidance

http://www.fws.gov/windenergy/PDF/Eagle%20Conservation%20Plan%20Guidance-Module%201.pdf

A Guide to Studying Wind and Wildlife Interactions: A Product of Collaboration with Stakeholders

This resource document of the Wildlife Workgroup is intended as a guide to persons involved in designing, conducting, or requiring wind energy/wildlife interaction studies.

The document follows a general framework for progressing through the decision process for a proposed wind project and a guide to methods and metrics for use in the necessary studies. The guide is relevant to the study of any wildlife species, although the focus is on birds and bats.



http://www.nationalwind.org//publications/comprehensiveguide.aspx

Research Collaborations with Stakeholders

As concerns about climate change and increasing costs and long-term environmental impacts from the use of fossil fuels have heightened, wind has become an increasingly important sector of the energy industry. Wind-generated electricity is renewable and generally considered environmentally clean. However, the direct and indirect local impacts of wind facilities on wildlife continue to be an issue and widespread instances of fatality of birds and bats have been reported.

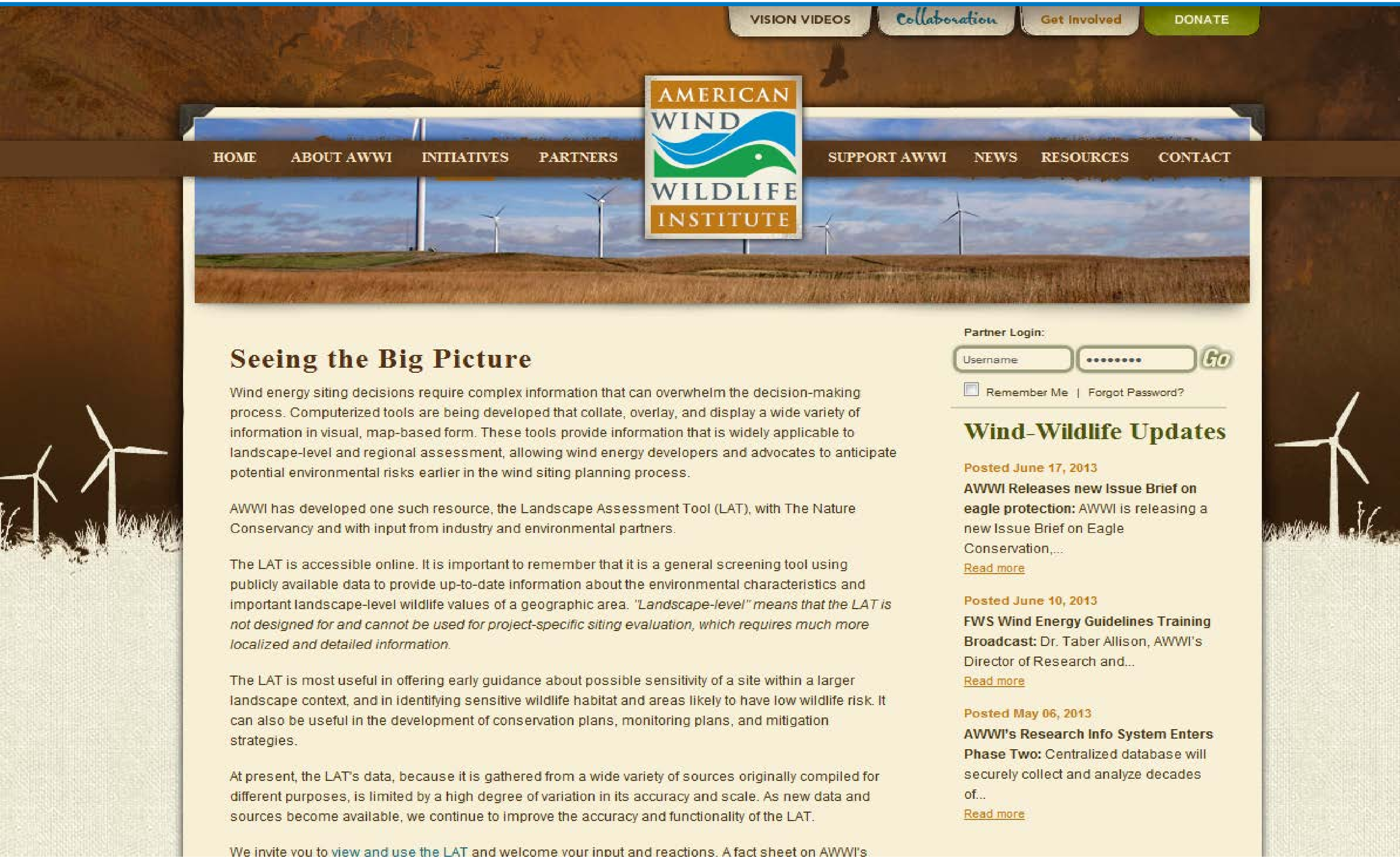
Unexpectedly high numbers of bat fatalities reported at wind energy sites, especially those on ridge tops in the eastern United States, have heightened the urgency to understand problems and find solutions.

The Bats and Wind Energy Cooperative (BWEC) was formed in 2003 by Bat Conservation International (BCI), the US Fish and Wildlife Service, the American Wind Energy Association (AWEA), and the National Renewable Energy Laboratory of the US Department of Energy (NREL). In addition to the founding organizations, BWEC also is funded by a diversity of partners.

BCI Founder and President Merlin Tuttle and Jessica Kerns, University of Maryland, inspect bats killed at wind turbines (photo by Merlin Tuttle, BCI.)

http://www.batsandwind.org/index.php

Research Collaborations with Stakeholders: The Landscape Assessment Tool (LAT)



http://www.awwi.org/initiatives/landscape.aspx

Recommended Ocean Wildlife Research Approach

- Collaborative approach involving the key stakeholders
- Quantitative science-based methods with independent science panel oversight
- Define metrics for impacts and their significance
- Baseline studies to measure and prioritize actual impacts to wildlife species and habitats
- Utilize both biological and device engineering capabilities to develop mitigation solutions
- Support and fund field testing of mitigation options
- Leveraging land-based experience to emerging offshore projects

Questions?

NREL Pics #24481

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