Impacts of wind energy development on bats: implications for conservation

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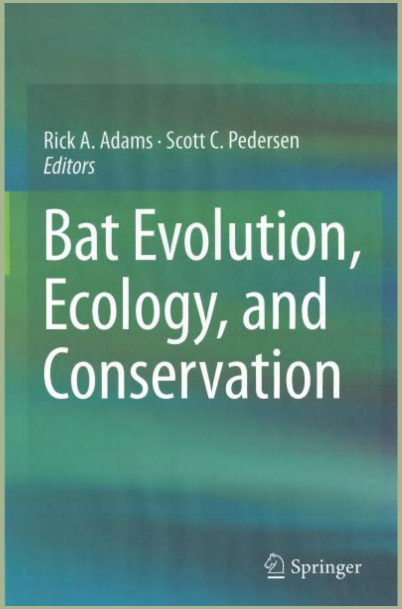
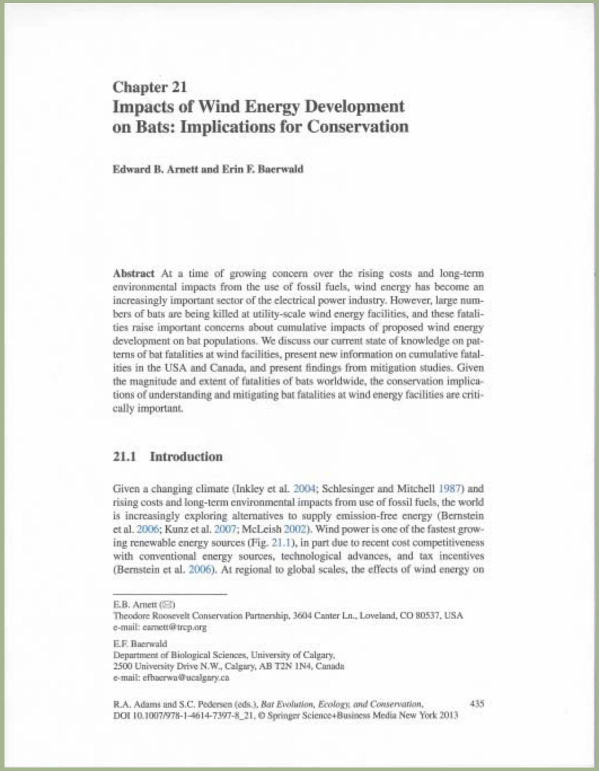
Summary of Bats and Wind Energy from 2000-2012

- 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 fuels, 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 patterns of bat fatalities at wind facilities, present new information on cumulative fatalities in the USA and Canada, and present findings from mitigation studies. Given the magnitude and extent of fatalities of bats worldwide, 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, technological advances, and tax incentives (Bernstein et al. 2006). At regional to global scales, the effects of wind energy on

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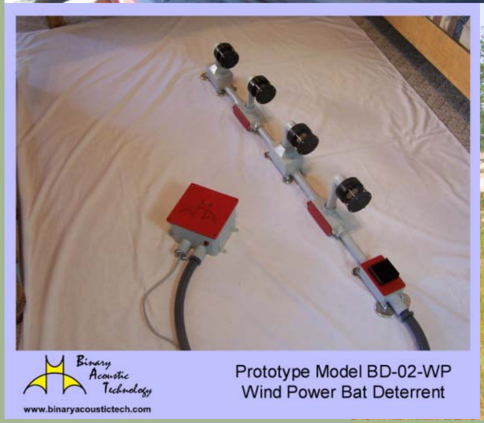
In 2003, between 1,398 and 4,031 bats estimated to have been killed at the Mountaineer Wind Energy Facility in West Virginia

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, pre-construction assessments, operational curtailment, and deterrents



Increasing number of studies

Possible Explanations Why Bats Are Being Killed by Wind Turbines?

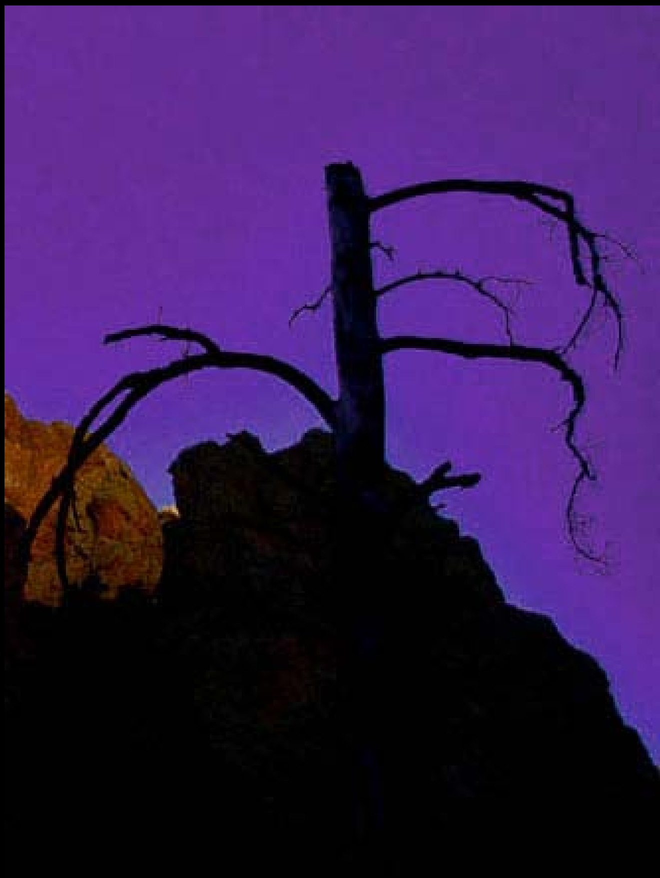
(from Kunz et al. 2007, Cryan and Barclay 2009)

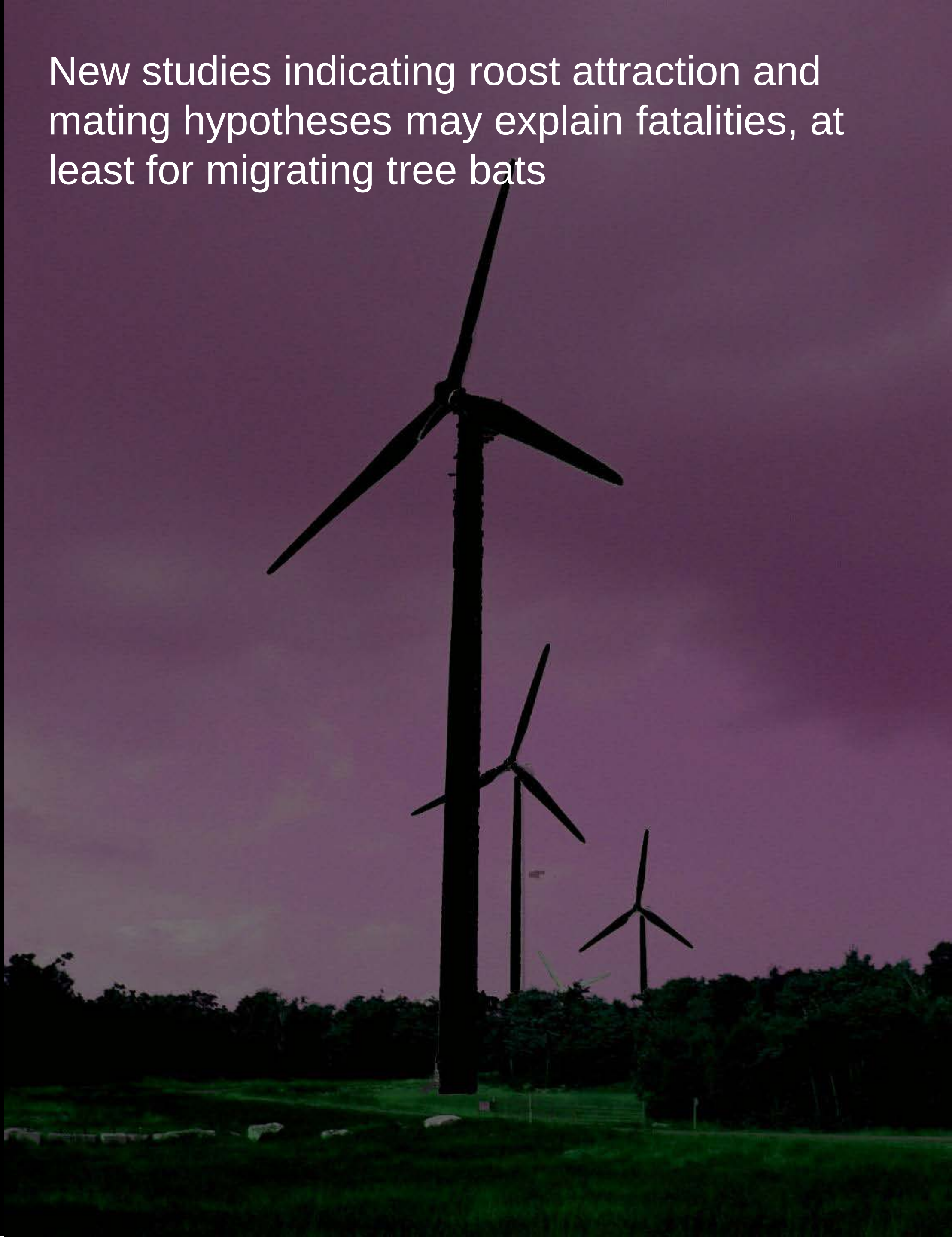
Proximate Causes (how killed)

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 tri-colored bats
- Brazilian free-tailed bats can be common where they occur in the Southwest U.S.

- To date, two endangered species has been found 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

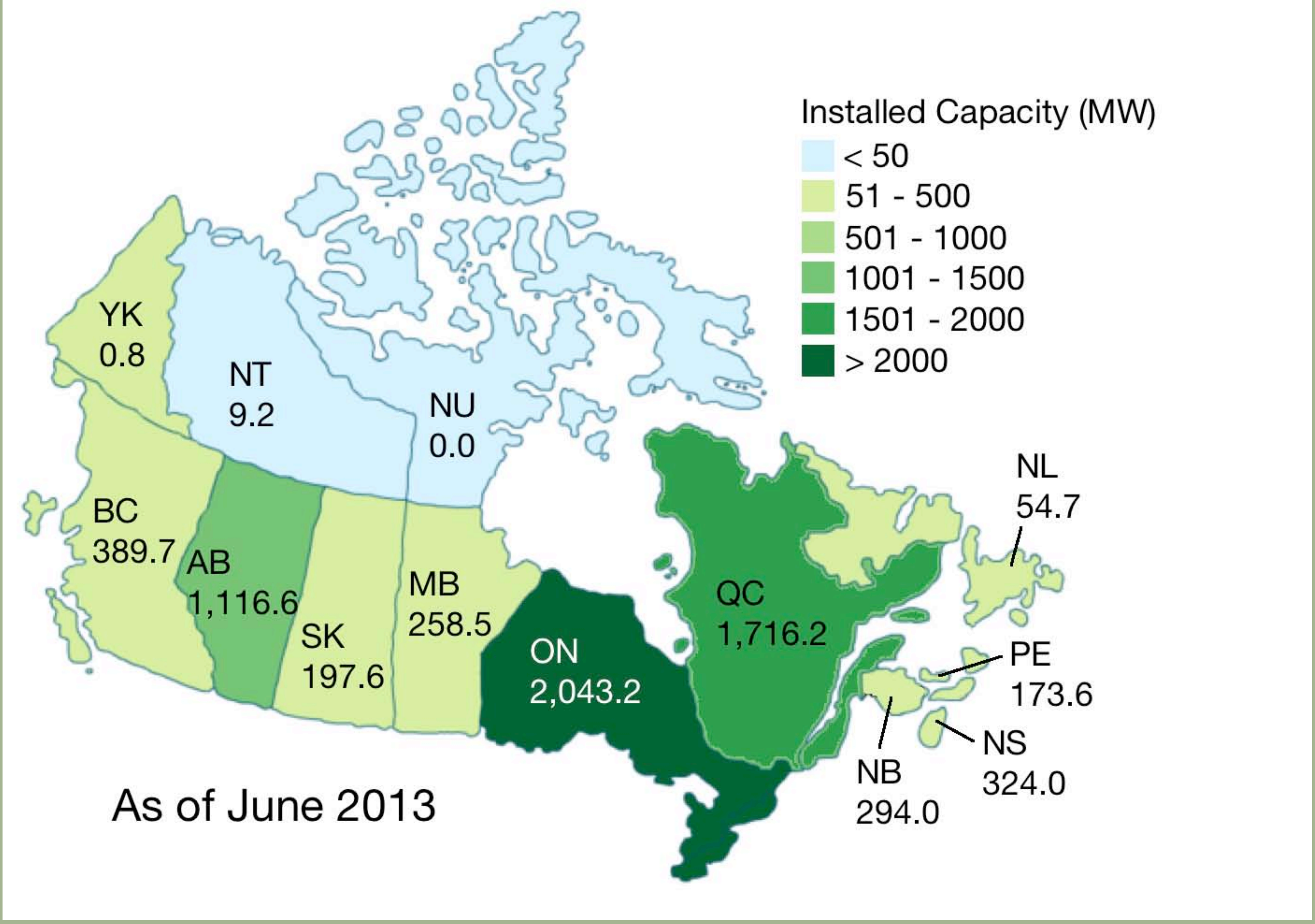

Eastern red bat

- 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…

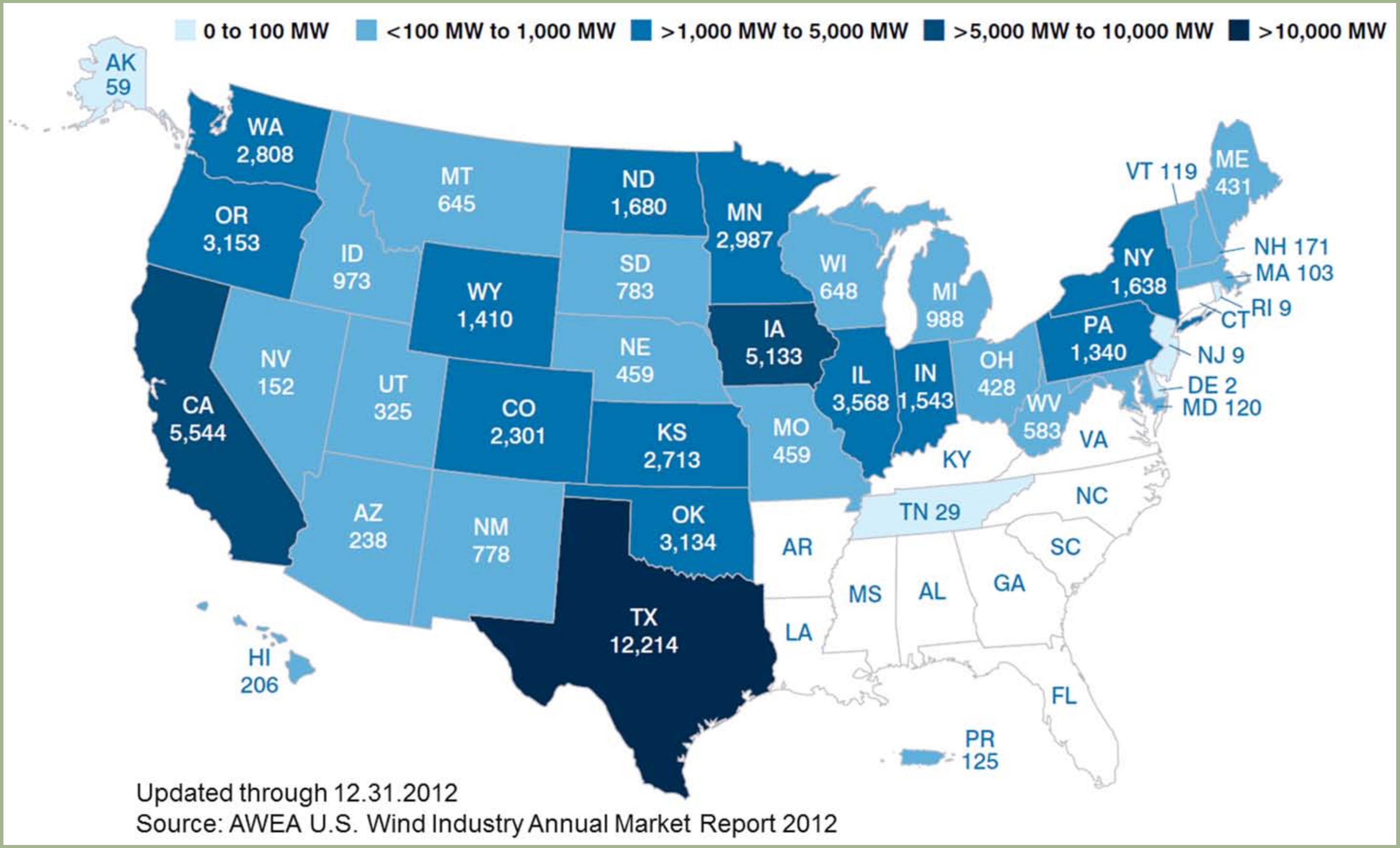

Silver-haired bat

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

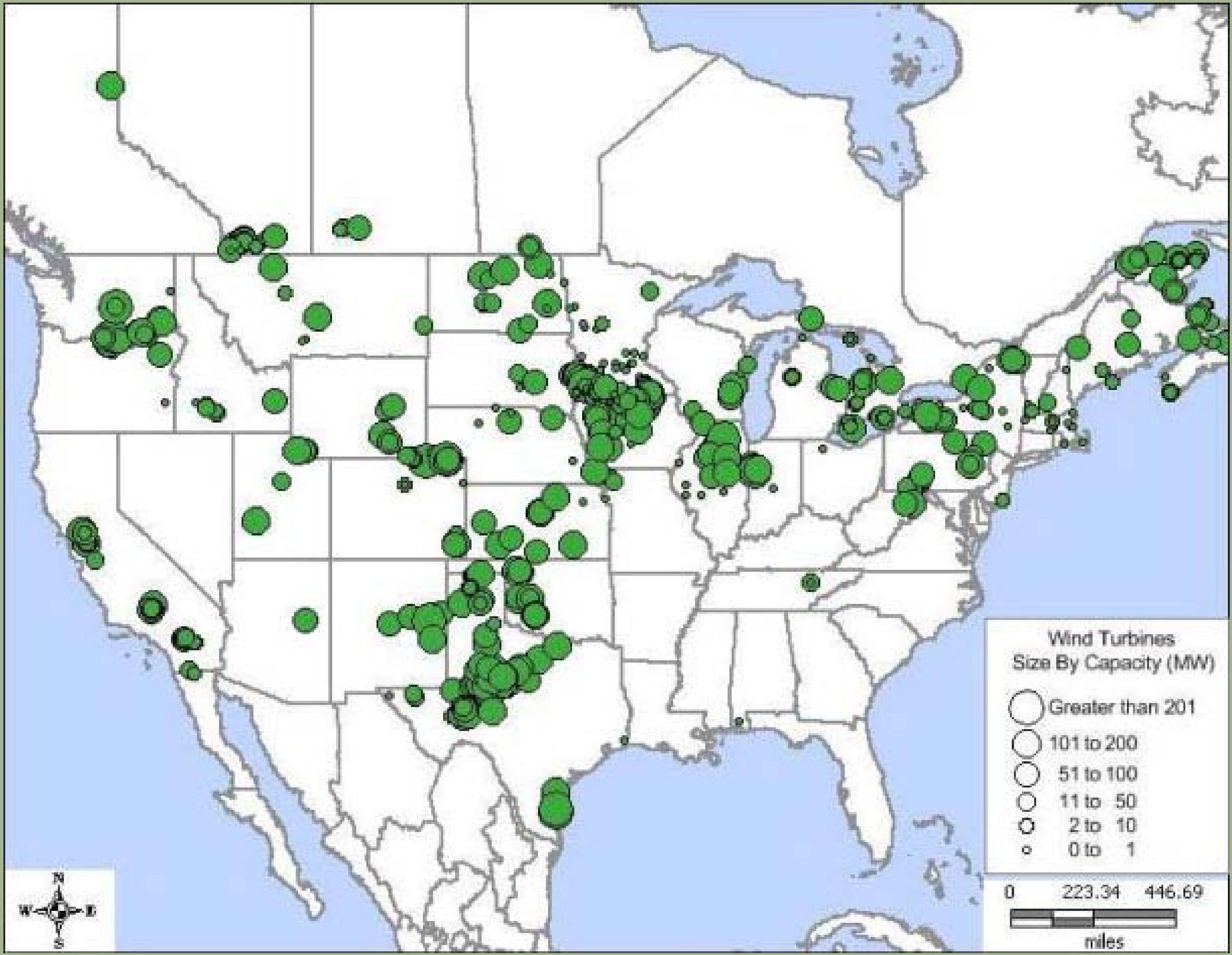
Distribution of wind energy in Canada



Distribution of wind energy in the U.S.

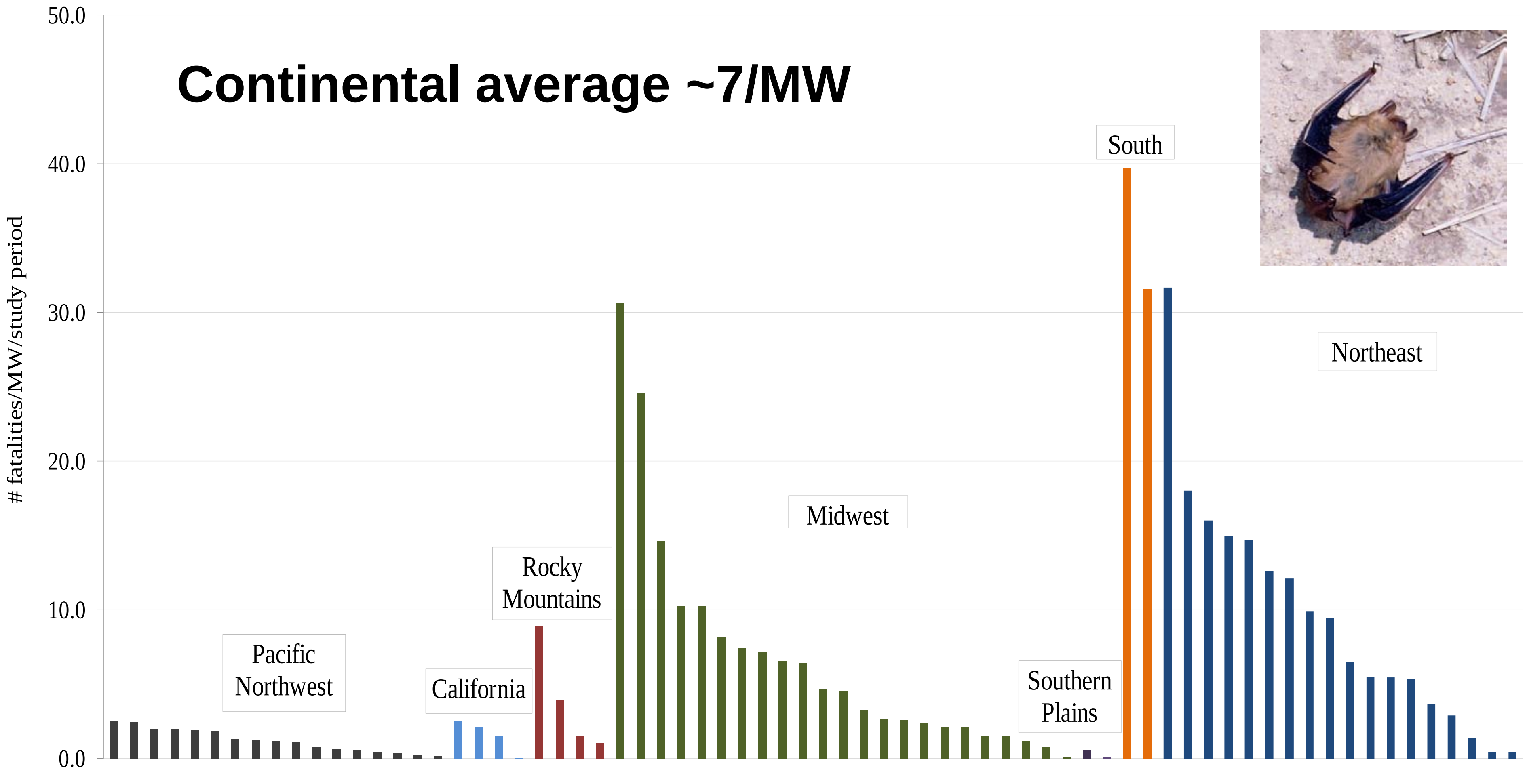


Uneven distribution of wind energy facilities



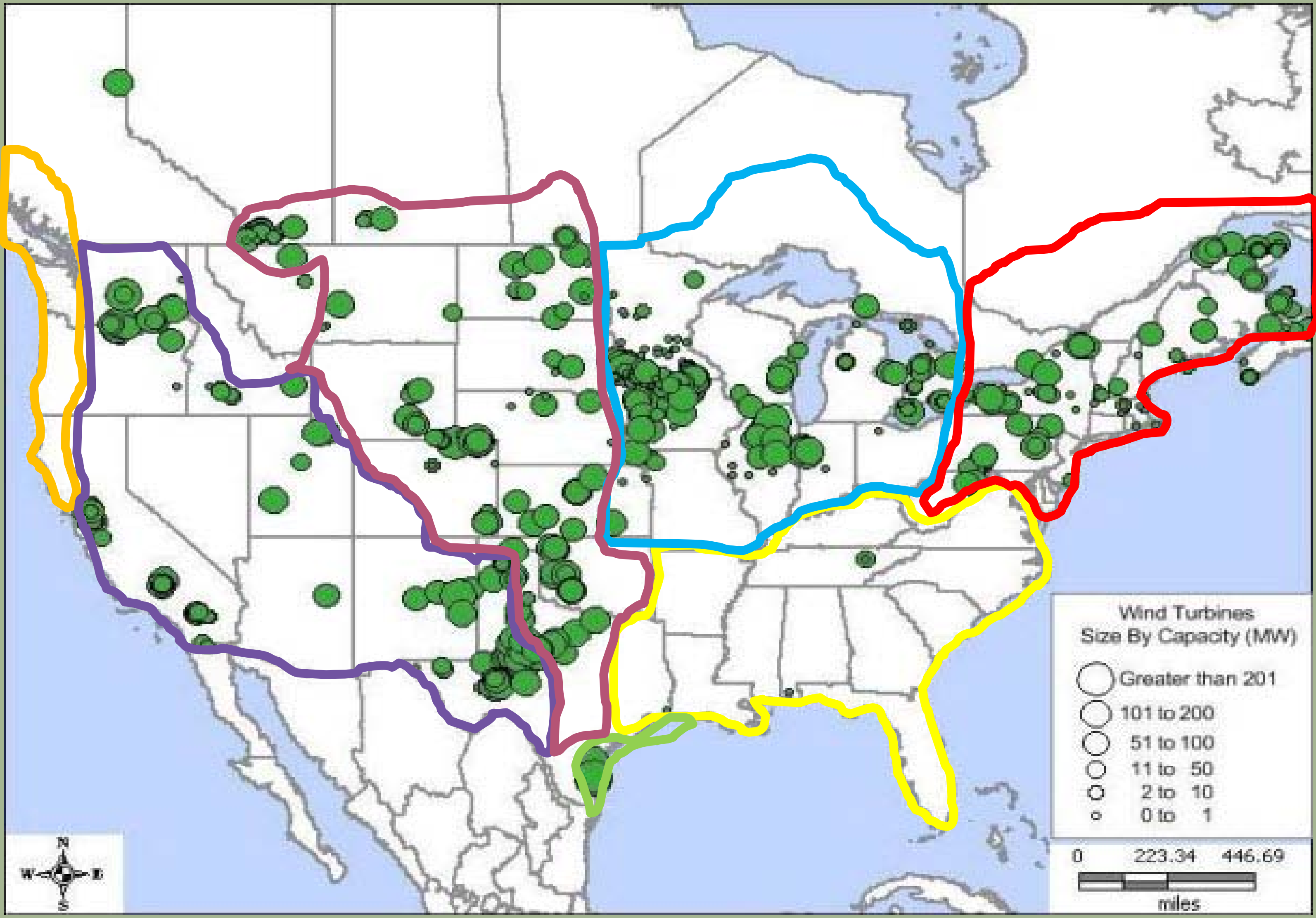
U.S. and Canada Regional Bat Fatality Estimates

(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-to-year 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

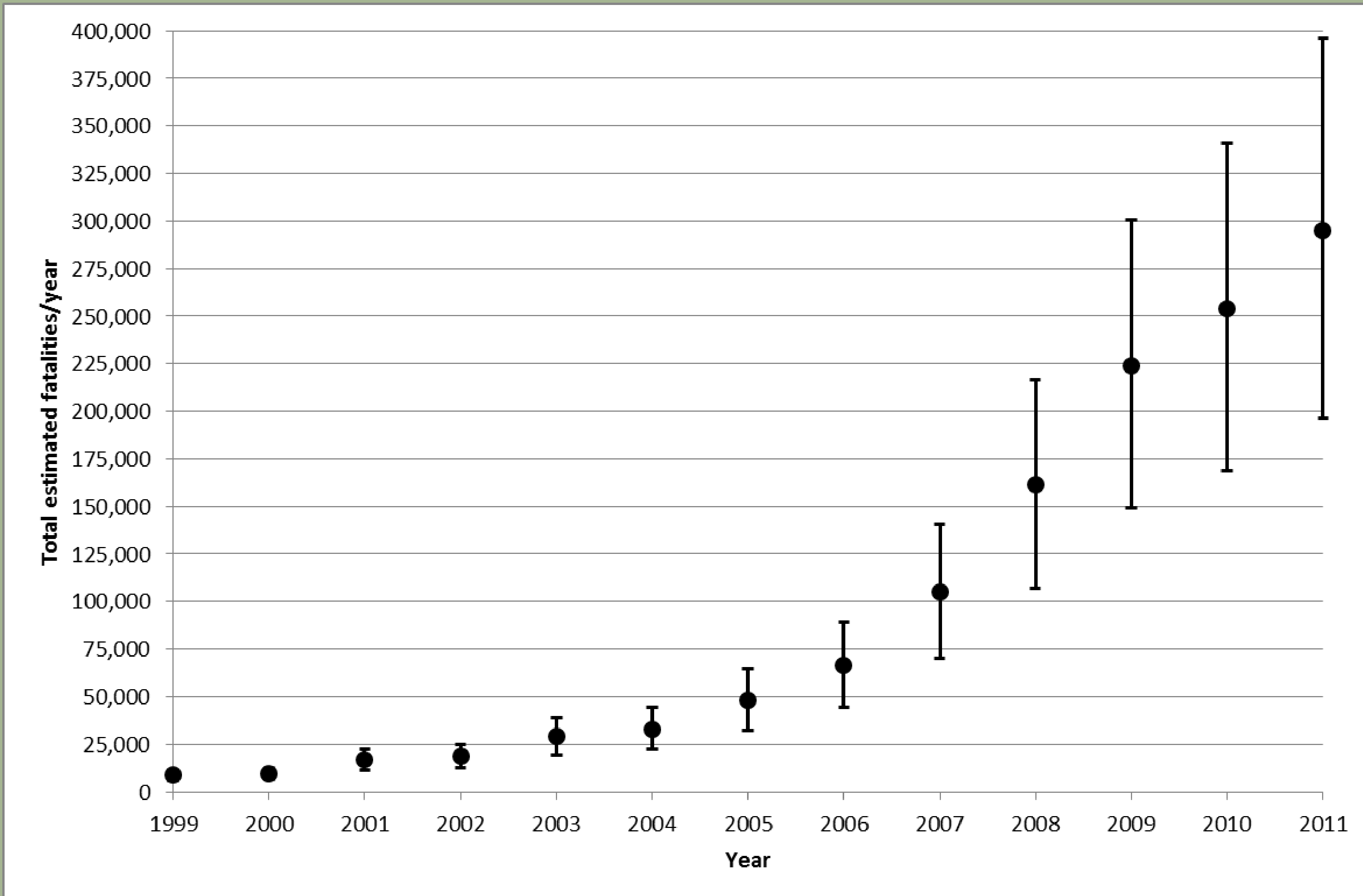
Cumulative Bat Fatalities:

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

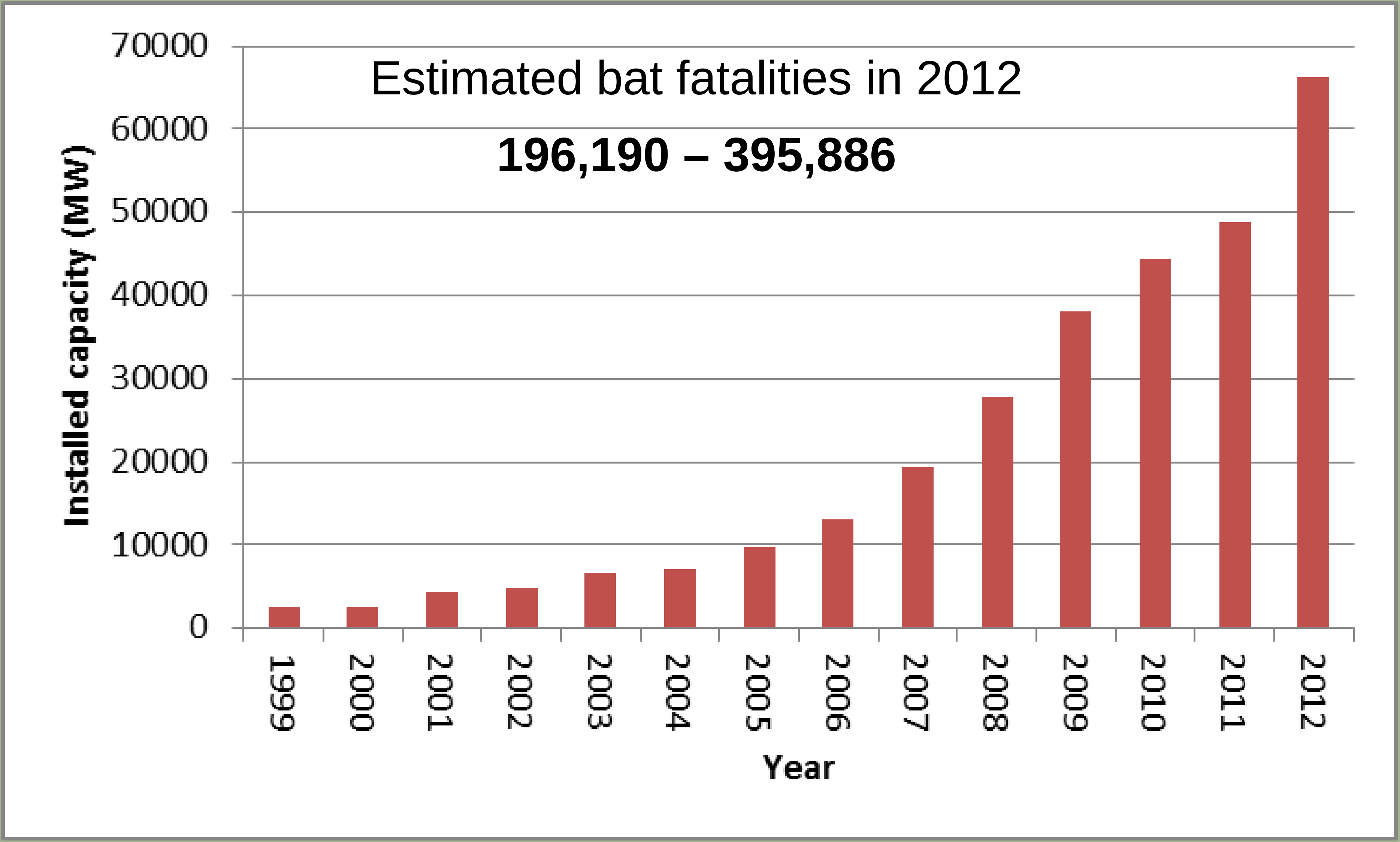
Mean bat fatalities from 2000-2011 =
1,261,622 (3.34-5.88/MW)

840,486 – 1,690,696

Estimates of bat fatalities/year



Installed capacity in Canada and the U.S.



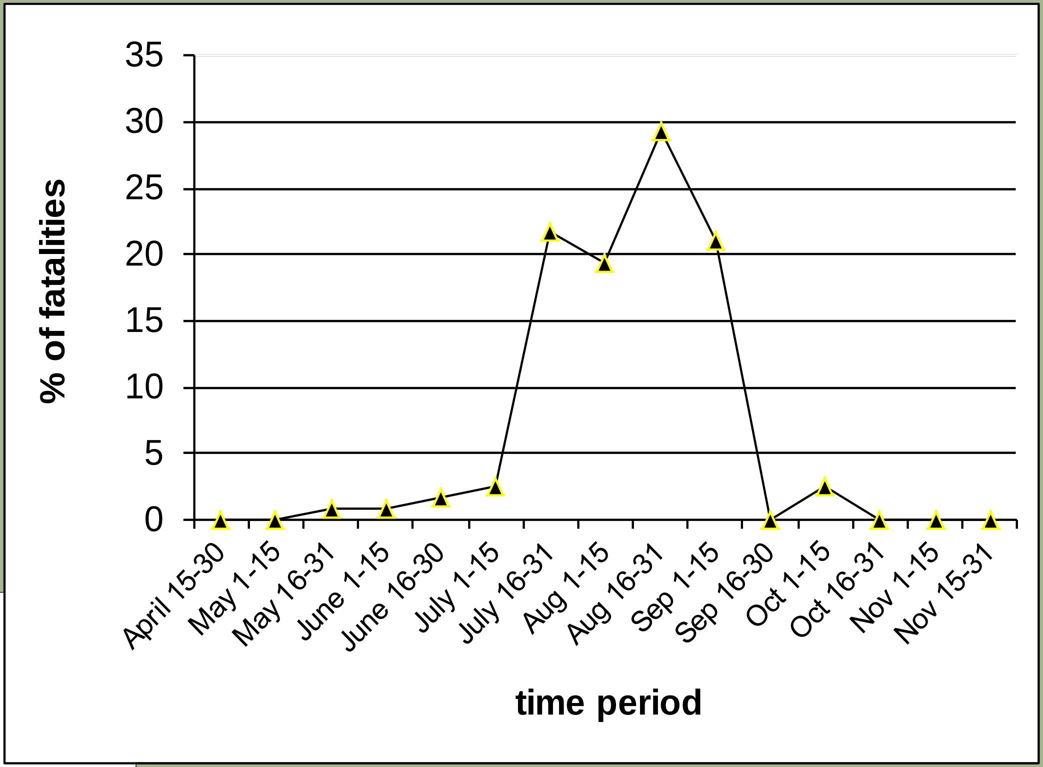
Patterns associated with fatalities

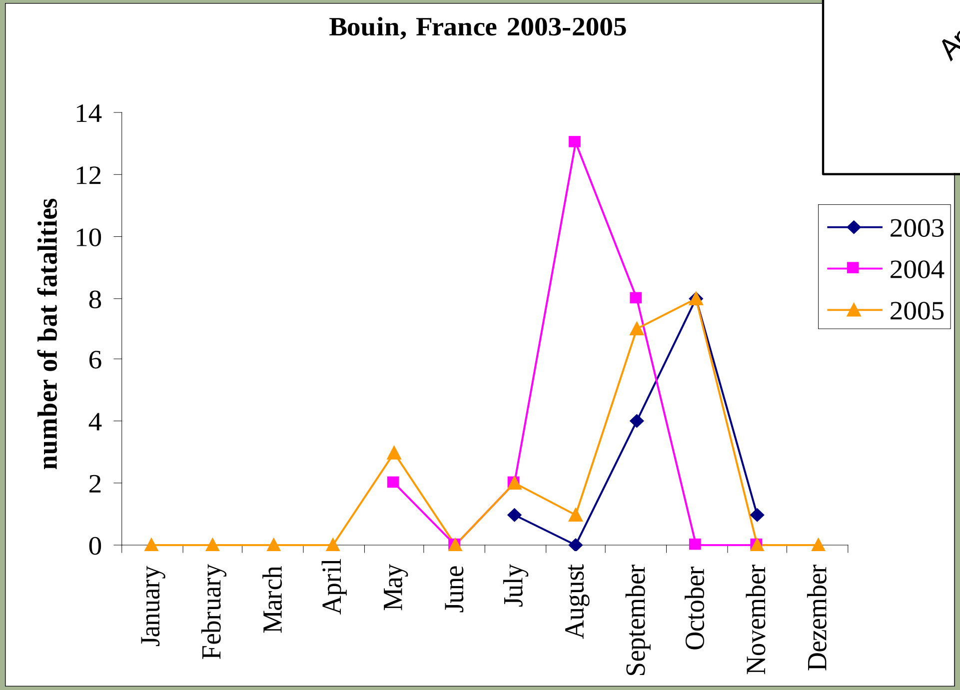
- Temporal
- Spatial
- Habitat relationships
- Weather and environmental variables



Temporal patterns

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



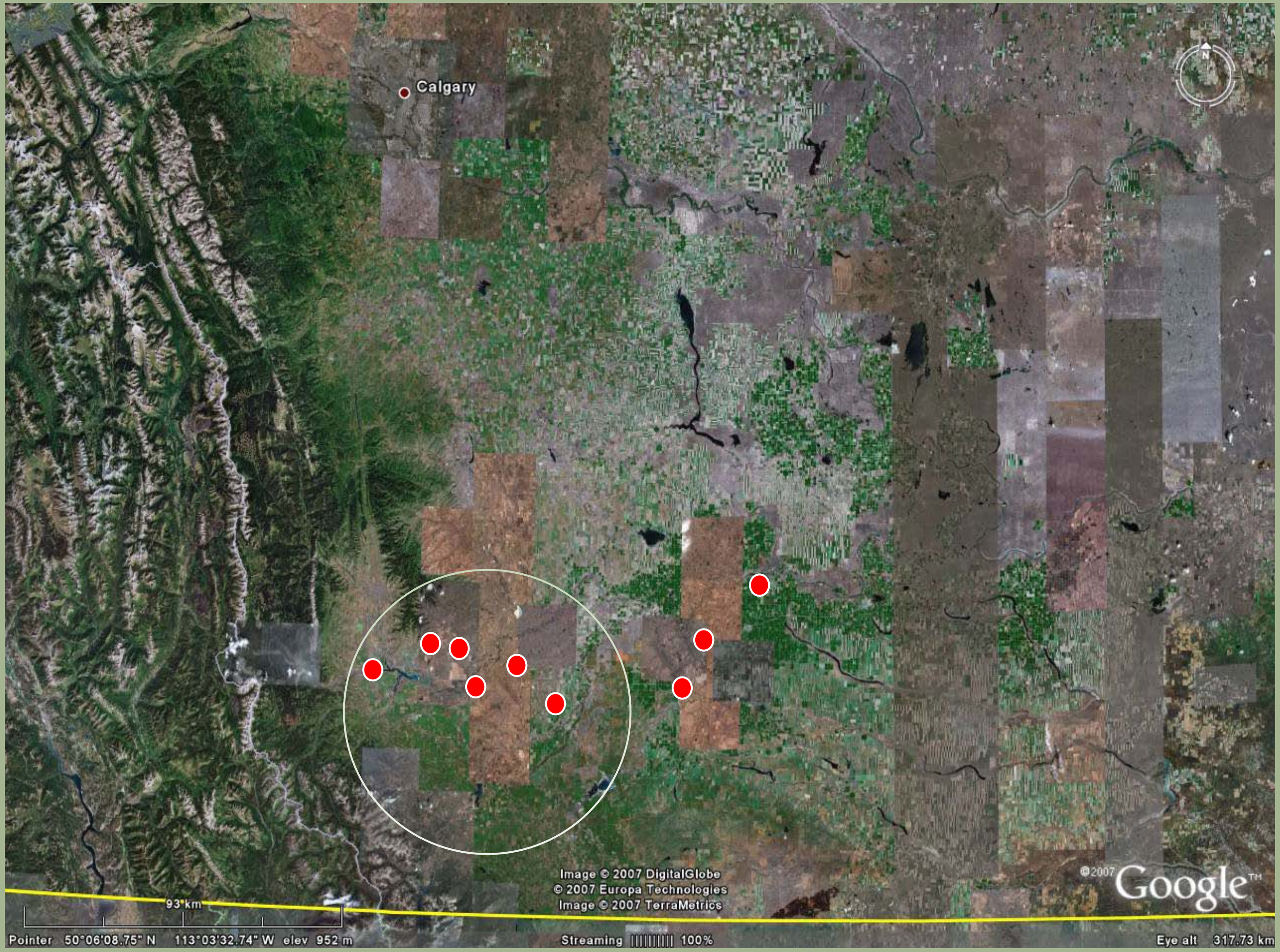


Spatial Patterns: site specific

- 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)



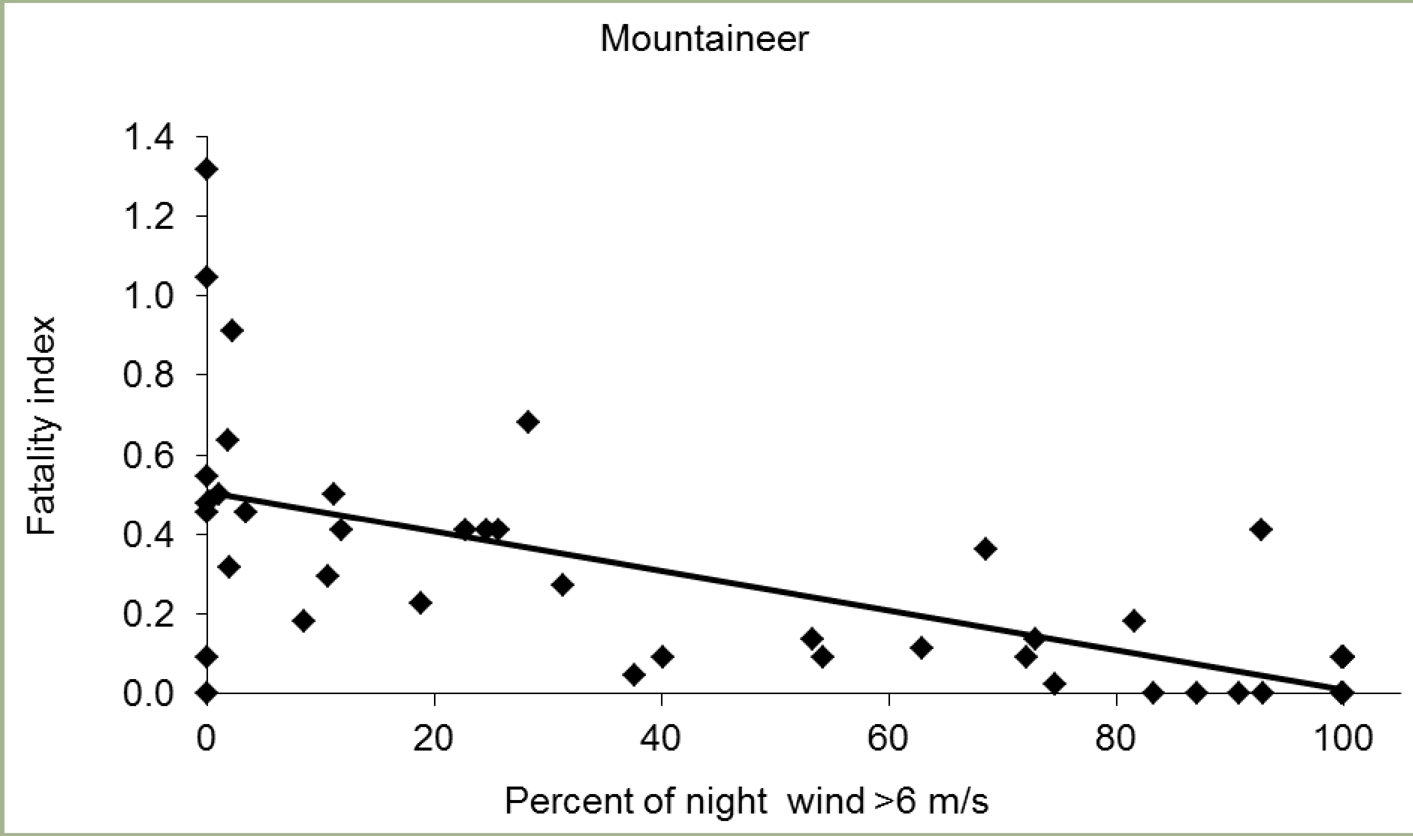
Bat fatalities have been found worldwide in many habitat conditions

Habitat Relationships

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

Weather and environmental factors

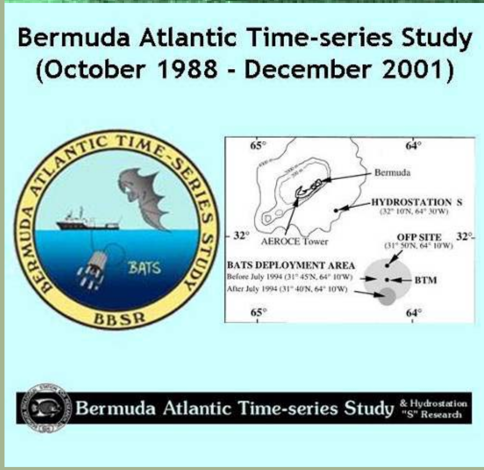
Bat fatalities are higher in low wind speeds
(Arnett et al. 2008, Rydell et al. 2010, Young et al 2010, 2011, Jain et al. 2011, Good et al. 2011)



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)

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- Offshore issues may have some similarities with those on-shore, 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 post-construction monitoring of fatalities offshore is seemingly hopeless

MITIGATION OPTIONS

Pre-Construction Assessment…
Determine and avoid high-risk areas

Operational mitigation…
Curtailment during high risk periods that may be predictable

Technological mitigation…
Deter or alert the bats

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

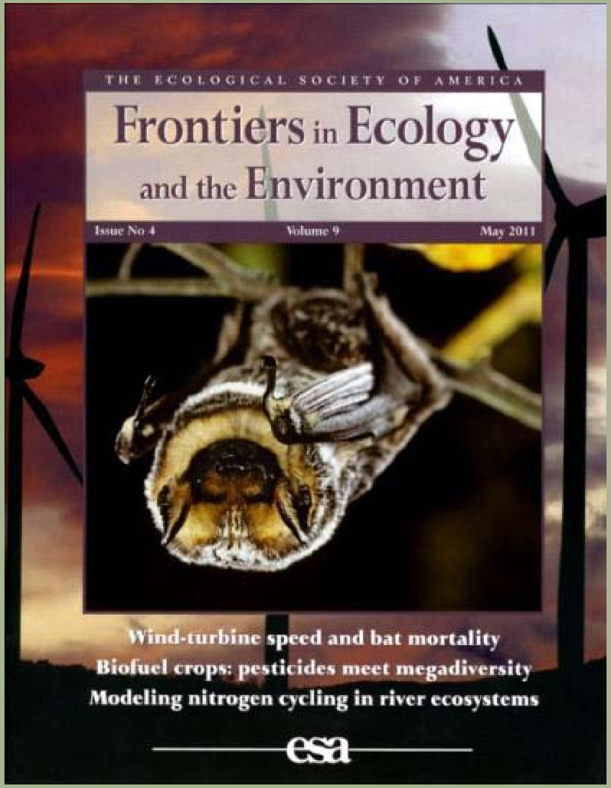
Supporting evidence

- 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 ~<u>60%</u> 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:

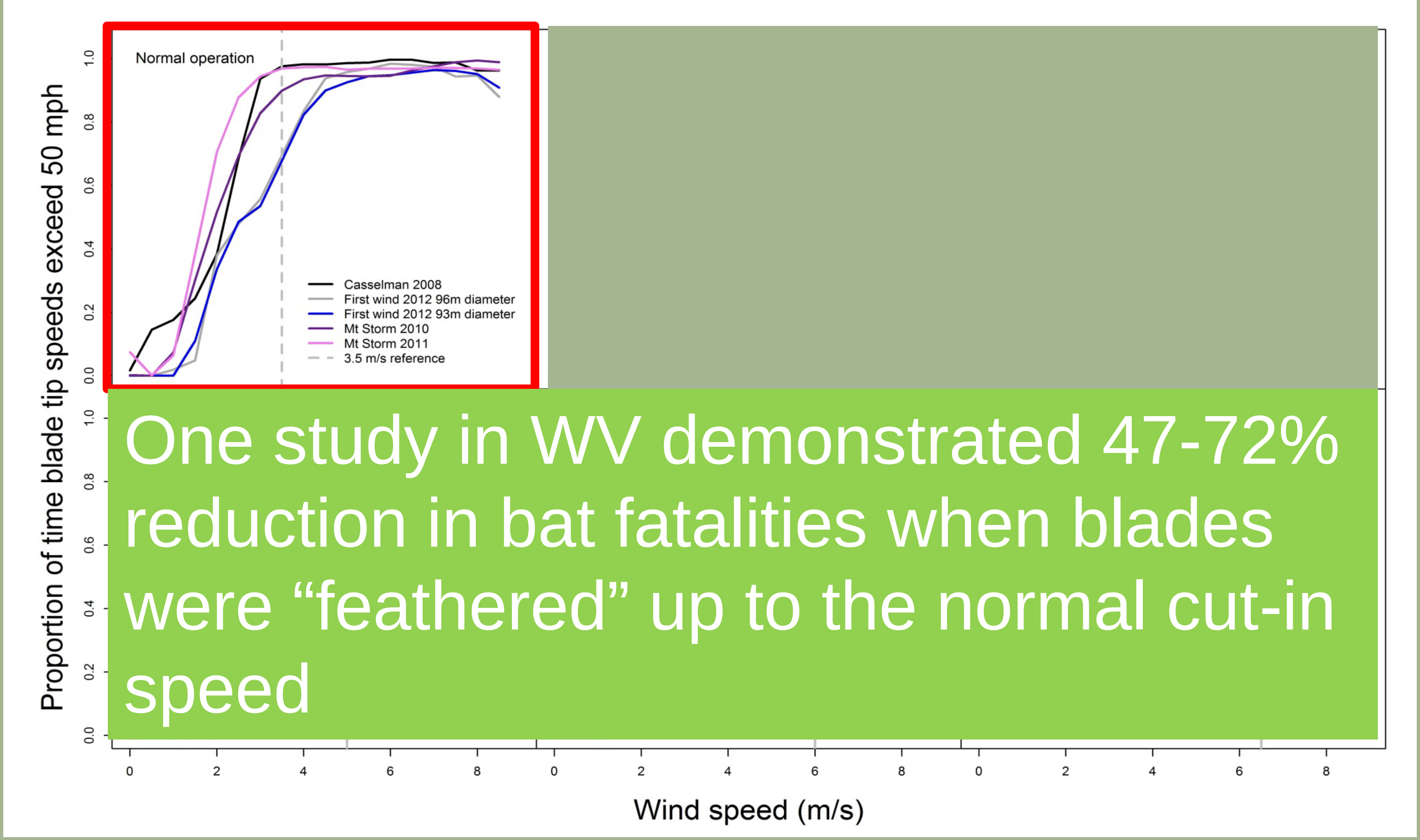
Fowler Ridge, IN - 50% and 78% reduction in bat fatality at 5.0 and 6.5 m/s, respectively (Good et al. 2011)

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

Mount Storm, WV - 72% and 23% 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)




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


DANGER
Wear Ear Protection.

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)

<u>CHALLENGE</u>: Coverage & attenuation!

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

Caution!

- We currently DO NOT 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 cost effectiveness

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


Many Thanks!