WIND TURBINES AS LANDSCAPE IMPEDIMENTS TO THE MIGRATORY CONNECTIVITY OF BATS

BY
PAUL M. CRYAN*

Unprecedented numbers of migratory bats are found dead beneath industrial-scale wind turbines during late summer and autumn in both North America and Europe. Prior to the wide-scale deployment of wind turbines, fatal collisions of migratory bats with anthropogenic structures were rarely reported and likely occurred very infrequently. There are no other well-documented threats to populations of migratory tree bats that cause mortality of similar magnitude to that observed at wind turbines. Just three migratory species comprise the vast majority of bat kills at turbines in North America and there are indications that turbines may actually attract migrating individuals toward their blades. Although fatality of certain migratory species is consistent in occurrence across large geographic regions, fatality rates differ across sites for reasons mostly unknown. Cumulative fatality for turbines in North America might already range into the hundreds of thousands of bats per year. Research into the causes of bat fatalities at wind turbines can ascertain the scale of the problem and help identify solutions. None of the migratory bats known to be most affected by wind turbines are protected by conservation laws, nor is there a legal mandate driving research into the problem or implementation of potential solutions.

* Research Biologist, United States Geological Survey, Fort Collins Science Center. The author thanks Robert Fischman, Jeffery Hyman, Vicky Meretsky, Andrea Need, Ellen Ketterson, Keith Clay, Heather Reynolds, and Rebecca Lave for organizing the *Animal Migration Conservation Symposium* and starting the cross-disciplinary discussions that inspired this work. Heather Reynolds, Elizabeth Baldwin, Edward Arnett, Marcos Gorresen, Justin Boyles, and Patricia Stevens provided very useful comments and insights regarding earlier manuscript drafts.

I. INTRODUCTION

Several species of insectivorous bats migrate hundreds to thousands of kilometers each spring and autumn, crossing a wide variety of landscape features and ecosystems on their journey.[1] These long-distance nocturnal flights, combined with the cryptic diurnal habits of migratory bats, have made it extremely difficult to uncover the details of their seasonal whereabouts, movements, and migration behaviors. Beginning around the turn of the millennium, a scatter of reports came to light regarding the surprising numbers of migratory bats found dead beneath wind turbines during autumn across both North America and Europe.[2] Since the release of these studies, mortality of migratory bats at wind turbines during late-summer and autumn has become a major conservation issue.[3] Whereas there were no known energy-related imminent threats to populations of migratory bats prior to about the year 2000, observed fatality rates of certain species at turbines now indicate the distinct possibility of population declines. At some sites, the estimated number of bats killed range from hundreds to over one thousand in a single autumn migration season, with cumulative estimates for

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1 *See* Thomas H. Kunz et al., *Ecological Impacts of Wind Energy Development on Bats: Questions, Research Needs, and Hypotheses*, 5 FRONTIERS ECOLOGY & ENV'T 315, 316, 319 (2007) (noting that three species of insectivorous bats—eastern red bats (*Lasiurus borealis*), hoary bats (*Lasiurus cinereus*), and tree cavity-dwelling silver-haired bats (*Lasionycteris noctivagans*)—travel great distances in migration); Theodore H. Fleming & Peggy Eby, *Ecology of Bat Migration*, *in* BAT ECOLOGY 156, 164–65 (Thomas H. Kunz & M. Brock Fenton eds., 2003) (explaining that some insectivorous migratory bats travel up to 1800 kilometers in migration).

2 Kunz et al., *supra* note 1, at 315–17.

3 *See* John Arnold McKinsey, *Regulating Avian Impacts Under the Migratory Bird Treaty Act and Other Laws: The Wind Industry Collides with One of Its Own, the Environmental Protection Movement*, 28 ENERGY L.J. 71, 72–73 (2007) (noting how increased bat deaths caused by wind energy development has created an issue of concern for environmentalists); Paul M. Cryan & Robert M.R. Barclay, *Causes of Bat Fatalities at Wind Turbines: Hypotheses and Predictions*, 90 J. MAMMALOGY 1330, 1331 (2009).

North America ranging into the hundreds of thousands per year, eclipsing any previously observed mortality of these mysterious migrants.[4] Over the past decade it has become apparent that wind turbines have the potential to seriously impede and disrupt the migration—and therefore long-term persistence—of several species of bats at a continental scale. Importantly, none of the migratory bats most affected by wind turbines are protected by national conservation laws or international treaties,[5] so legal mandates for researching and finding practical solutions to the problem are lacking.

This Article describes the unprecedented bat mortality caused by wind turbines, and the potentially disastrous effects on certain bat populations. Current laws may be insufficient to protect bat migrations, and additional research is needed to identify effective conservation solutions. Part II includes an overview of migration in bats and emphasizes how little we know about this phenomenon. Part III discusses the inherent risks of migration in bats, including both natural and human-caused mortality. Part IV provides background on the emerging problem of bat fatalities at wind turbines and compares turbine-induced mortality to other known sources of mortality in migrating bats. Part V highlights the importance of scientific research in understanding the scope and magnitude of bat mortality at turbines, and in developing effective solutions to the problem. The Article concludes by identifying the challenges associated with developing research and conservation strategies aimed at poorly understood migratory species that are not protected by law.

II. THE UNIQUE AND MYSTERIOUS MIGRATIONS OF BATS

There are approximately 5400 species of mammals on Earth, of which about 1100 are bats.[6] Bats occur nearly everywhere but Antarctica and some remote islands, playing important functional roles in the majority of our

4 *See* Kunz et al., *supra* note 1, at 318 tbl.1.1 (noting hundreds to over one thousand annual bat fatalities reported at some wind energy facilities); *id.* at 319 (highlighting substantial bat fatality rates at wind energy sites projected by models predicting migratory bat fatalities to range anywhere from 33,000 to over 111,000 deaths in the Mid-Atlantic Highlands region in the year 2020); *see also* U.S. Geological Survey, Dep't of the Interior, Bat Fatalities at Wind Turbines: Investigating the Causes and Consequences, http://www.fort.usgs.gov/batswindmills/ (last visited Apr. 10, 2011) (explaining that several wind energy sites are estimated to annually cause thousands of deaths).

5 The possible exception to this statement is that a subspecies of one of these "migratory bats most affected by wind turbines" is protected under federal law and might be susceptible to wind turbines. The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is a subspecies listed as endangered under the Endangered Species Act of 1973, 16 U.S.C. §§ 1531–1544 (2006). *See infra* Part V.A.

6 Don E. Wilson, *Preface*, *in* MAMMAL SPECIES OF THE WORLD: A TAXONOMIC AND GEOGRAPHIC REFERENCE (Don E. Wilson & DeeAnn M. Reeder eds., Johns Hopkins Univ. Press 3d ed. 2005), *available at* http://www.bucknell.edu/msw3/preface.html (listing the total number of mammals and bats (*Chiroptera*) found in the world as of the publishing of the third edition).

planet's terrestrial ecosystems.[7] In tropical and subtropical regions where species diversity is highest, bats pollinate flowers, disperse seeds, prey on small terrestrial vertebrates, and consume nocturnal insects.[8] Temperate zones of the world are occupied mostly by insectivorous bats that consume vast quantities of nocturnal flying insects during the warmer months.[9] Forty-five species of bats occur in the continental United States, and all but three species eat nothing but insects.[10]

A. Winter Survival Strategies

Bats, as flying insect predators, have evolved a spectrum of strategies for surviving seasonally harsh conditions and winter absence of prey. One general winter survival strategy, exhibited by about half of the bats occurring in the United States, involves moving tens to hundreds of kilometers from summer habitats to underground shelters, such as caves and mines.[11] There, bats lower their metabolism and body temperatures for several months to save energy during the process of their hibernation, which allows them to live off of stored fat reserves throughout the winter. At a

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7 *See* Thomas H. Kunz & Elizabeth D. Pierson, *Introduction* to RONALD M. NOWAK, WALKER'S BATS OF THE WORLD 1, 1, 25–26 (1994); Thomas H. Kunz et al., *Ecosystem Services Provided by Bats*, 1223 ANNALS N.Y. ACAD. SCI. 1 (2011) (describing the "keystone role" of bats in many different kinds of ecosystems); Paula Federico et al., *Brazilian Free-Tailed Bats as Insect Pest Regulators in Transgenic and Conventional Cotton Crops*, 18 ECOLOGICAL APPLICATIONS 826 (2008).

8 *See* Kuntz & Pierson, *supra* note 7, at 26; *see also* M. B. Fenton & T. H. Fleming, *Ecological Interactions Between Bats and Nocturnal Birds*, 8 BIOTROPICA 104, 105–06 (1976) (highlighting the diets of bat species inhabiting the neotropical ecozone and noting that diets of carnivorous bats include "a variety of vertebrates including bats, birds, and terrestrial and arboreal lizards and rodents").

9 *See* Kuntz & Pierson, *supra* note 7, at 1–3 (describing the distributions of the families *Rhinolophidae*, *Mystacinidae*, *Vespertilionidae* and *Molossidae*, as "penetrating into the cool temperate regions"); NOWAK, *supra* note 7, at 107–10, 176–78, 184–86, 230–32 (describing the distributions and characteristics of the *Rhinolophidae*, *Mystacinidae*, *Vespertilionidae*, and *Molossidae* families of insectivorous bats, respectively); Justin G. Boyles, Paul M. Cryan, Gary F. McCracken & Thomas H. Kunz, *Economic Importance of Bats in Agriculture*, 332 SCIENCE 41 (2011) (same); Cutler J. Cleveland et al., *Economic Value of The Pest Control Service Provided by Brazilian Free-Tailed Bats in South-Central Texas*, 4 FRONTIERS ECOLOGY & ENV. 238 (2006) (describing the quantities of insects consumed by insectivorous bats); Kunz et al., *supra* note 7 (same).

10 Thomas J. O'Shea & Michael A. Bogan, *Introduction* to MONITORING TRENDS IN BAT POPULATIONS OF THE UNITED STATES AND TERRITORIES 1, 2 (Thomas J. O'Shea & Michael A. Bogan, eds., 2003); Theodore H. Fleming et al., *Current Status of Pollinating Bats in Southwestern North America*, *in* MONITORING TRENDS IN BAT POPULATIONS OF THE UNITED STATES AND TERRITORIES, *supra*, at 63, 63.

11 John R. Speakman & Donald W. Thomas, *Physiological Ecology and Energetics of Bats*, *in* BAT ECOLOGY, *supra* note 1, at 430, 456–63; *see* Merlin D. Tuttle, *Estimating Population Sizes of Hibernating Bats in Caves and Mines*, *in* MONITORING TRENDS IN BAT POPULATIONS OF THE UNITED STATES AND TERRITORIES, *supra* note 10, at 31, 32 (discussing the prevalence of hibernation in bats in the United States); Donald R. Griffin, *Migrations and Homing of Bats*, *in* 1 BIOLOGY OF BATS 233, 233, 242–44 (William A. Wimsatt ed., 1970) (discussing the "widespread habit" of winter hibernation in caves and migration lengths of hibernating species).

different end of the spectrum, other bat species occurring in the United States either reside all year in warm areas or migrate from colder summering grounds across hundreds to thousands of kilometers to lower latitudes and warmer climates during the winter, where they continue feeding or sporadically enter daily torpor[12] when prey becomes scarce.[13] Unlike migratory birds, few, if any, species of migratory bats regularly make intercontinental movements.[14] For example, no bats migrate between the Americas and other continents nor are any known to consistently make long-distance movements from North to South America.[15] The longest known bat migrations are about 2000 kilometers.[16] Regardless, these mysterious migrations have been difficult for researchers to study.

B. The Elusive Bat: Research Challenges

Although many species of temperate zone bats migrate long distances, the details of their migratory movements and seasonal whereabouts are mostly lacking. As with many species of migratory songbirds, bat migration occurs at night under the cover of darkness.[17] Birds and other migratory animals that are active during the day may be tracked by observing where they appear during the course of day-to-day migration. This approach is not possible with many bats because most migratory bats are inactive during the day and hide so well that they are rarely found in their natural roosts during migration periods without substantial effort (e.g., radio tracking).[18] Caves, abandoned mines, rock crevices, tree cavities, and tree foliage conceal bats so well that, for many species, we are just beginning to form a coarse understanding of the seasonal whereabouts and habitats of their

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12 "Torpor" is a physiological state when body temperature and metabolic rate are lowered to save energy. It is a similar process to hibernation, but occurs over shorter periods of time (hours to days) and throughout the year. *See* Fritz Geiser, *Evolution of Daily Torpor and Hibernation in Birds and Mammals: Importance of Body Size*, 25 CLINICAL & EXPERIMENTAL PHARMACOLOGY & PHYSIOLOGY 736, 736 (1998).

13 *See* GERHARD NEUWEILER, THE BIOLOGY OF BATS 68 (Ellen Covey trans., Oxford Univ. Press 2000).

14 Fleming & Eby, *supra* note 1, at 196.

15 *See id.* at 195–96.

16 *See* RAINER HUTTERER ET AL., FED. AGENCY FOR NATURE CONSERVATION [BFN] (GER.), BAT MIGRATIONS IN EUROPE: A REVIEW OF BANDING DATA AND LITERATURE 110 (2005); Paul M. Cryan et al., *Stable Hydrogen Isotope Analysis of Bat Hair as Evidence for Seasonal Molt and Long-Distance Migration*, 85 J. MAMMALOGY 995, 996 (2004).

17 *See* NAT'L WIND COORDINATING COLLABORATIVE, U.S. DEP'T OF ENERGY, WIND TURBINE INTERACTIONS WITH BIRDS, BATS AND THEIR HABITAT: A SUMMARY OF RESEARCH RESULTS AND PRIORITY QUESTIONS 4, 6–7 (2010), *available at* http://www1.eere.energy.gov/windandhydro/pdfs/birds_and_bats_fact_sheet.pdf.

18 As an example of the paucity of information on the locations where certain bats seasonally occur, there are no published studies that describe the wintering habitats or behaviors of hoary bats (*Lasiurus cinereus*), one of the most wide-ranging migratory species in North America. *See, e.g.*, Michael A. Menzel et al., *A Review of the Distribution and Roosting Ecology of Bats in Georgia*, 58 GA. J. SCI. 143, 143, 145–46, 161–62 (2000).

populations. However, very little is known of the migration behaviors or long-distance movements of individual bats.

Compounding the difficulty of predicting where migratory bats are likely to occur during certain times of year is the fact that few observations of actively migrating bats have ever been recorded. A substantial body of direct and circumstantial evidence for long-distance migration leaves little doubt about the existence of such movements, but the details of how bats migrate remain almost completely unknown.[19]

C. Unique Migration Behaviors of Bats

Unique migration behaviors likely evolved in bats in response to natural selection acting on their distinctive thermoregulatory[20] strategies and life histories.[21] For example, temperate zone bats differ from many other long-distance aerial migrants in that they mate during autumn and winter.[22] Females often migrate in spring while pregnant, moving to habitats and regions of the continent separate from males during the early summer.[23] Additionally, most species can drop their metabolism throughout the year and enter torpor to save energy when climate, weather, or food availability is unfavorable.[24]

Bats have high rates of adult survival, which results in longevity: individuals of at least ten to tenty years old have been documented in many species[25] and there are recent records of some bats reaching at least forty years old.[26] Reproductive success is high in bats, and for mammals of their size, they produce a small number of young and put considerable time and energy into taking care of them.[27] These life-history traits result in bat populations growing slowly and an inability to quickly rebound after rapid

19 Paul M. Cryan & Robert H. Diehl, *Analyzing Bat Migration*, *in* ECOLOGICAL AND BEHAVIORAL METHODS FOR THE STUDY OF BATS 476, 476 (Thomas H. Kunz & Stuart Parsons eds., 2d ed. 2009); HUTTERER ET AL., *supra* note 16, at 11.

20 "Thermoregulatory" is defined as serving to maintain a body at a particular temperature whatever its environmental temperature. WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 2374 (3d ed. 2002).

21 Paul M. Cryan & Blair O. Wolf, *Sex Differences in the Thermoregulation and Evaporative Water Loss of a Heterothermic Bat,* Lasiurus cinereus*, During Its Spring Migration*, 206 J. EXPERIMENTAL BIOLOGY 3381, 3388 (2003).

22 *Id.* at 3381–82.

23 *Id.*

24 *Id.*

25 Merlin D. Tuttle & Diane Stevenson, *Growth and Survival of Bats*, *in* ECOLOGY OF BATS 105, 133 tbl.IV (Thomas H. Kunz ed., 1982).

26 Andrej J. Podlutsky et al., *A New Field Record for Bat Longevity*, 60 J. GERONTOLOGY: BIOLOGICAL SCI. 1366, 1366 (2005).

27 *See* Robert M. R. Barclay & Lawrence D. Harder, *Life Histories of Bats: Life in the Slow Lane*, *in* BAT ECOLOGY, *supra* note 1, at 209, 216, 218 (discussing life history characteristics of bats and comparing them to shrews); Paul A. Racey & Abigail C. Entwistle, *Conservation Ecology of Bats*, *in* BAT ECOLOGY, *supra* note 1, at 680, 687 (mentioning the low reproductive rates of banded bats discovered in demographic studies).

declines in population size.[28] For these reasons, migration behaviors of bats may be unlike those of any other migratory animals.

III. PERILS OF MIGRATION IN BATS

Migration is an inherently risky business. Like other taxa that migrate, difficulties associated with the conservation of migratory bats include their dependence on widely dispersed and mostly uncharacterized habitats, their propensity to become concentrated in distribution during migration, and their regular crossing of political and administrative boundaries.[29]

A. Species Characteristics Indicate Higher Natural Mortality in Migratory Bats

Certain species of migratory bats show signs of experiencing higher natural mortality than species that do not migrate.[30] Most bat species in the United States have one offspring per year.[31] Exceptions to this pattern are found in the species that dwell in the foliage or trunks of trees year round and migrate across several degrees of latitude, the so-called migratory "tree bats."[32] In North America, this unique group includes the hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*), western red bat (*Lasiurus blossevillii*), and silver-haired bat (*Lasionycteris noctivagans*), among others. These species regularly give birth to twins, and species of *Lasiurus* may sometimes successfully birth triplets and quadruplets.[33] The characteristic of higher reproductive output in species of tree bats may reflect a need to compensate for higher natural mortality associated with roosting in exposed roosts year-round and migrating. Observations of bats dying during migration due to natural causes are rare, but are presumed to include stress, storms, and predation.[34]

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28 Racey & Entwistle, *supra* note 27, at 690–91.

29 Fleming & Eby, *supra* note 1, at 191; *see also* Peter P. Marra, David Hunter & Anne M. Perrault, *Migratory Connectivity and the Conservation of Migratory Animals*, 41 ENVTL. L. 317, 319 (2011).

30 *See, e.g.*, Fleming & Eby, *supra* note 1, at 184 (highlighting data that indicates migrating tropical bat species have shorter life expectancies than hibernating temperate bat species).

31 *See* Kunz & Pierson, *Bats of the World: An Introduction*, *in* WALKER'S BATS OF THE WORLD, *supra* note 7, at 1, 19 (noting a "general pattern" for females of bat species residing in temperate regions to birth one young per year); NAT'L WILDLIFE FED'N, NIGHT FRIENDS-AMERICAN BATS 3, *available at* http://www.nwf.org/Wildlife/Wildlife-Library/Mammals/~/media/PDFs/Wildlife/batguide.ashx.

32 Donald R. Griffin, *Migration and Homing of Bats*, *in* 1 BIOLOGY OF BATS, *supra* note 11, at 233, 233–35.

33 Fleming & Eby, *supra* note 1, at 184 (reporting that *Lasiurus* "produce two or more pups per pregnancy").

34 *See* David D. Gillette & John D. Kimbrough, *Chiropteran Mortality*, *in* ABOUT BATS: A CHIROPTERAN BIOLOGY SYMPOSIUM 262, 265, 274 (Bob H. Slaughter & Dan W. Walton eds., 1970); Victoria J. Byre, *A Group of Young Peregrine Falcons Prey on Migrating Bats*, 102 WILSON BULL. 728, 729 (1990) (describing observations of natural bat deaths by predation); R. E. Mumford,

B. Migratory Bat Collisions with Human-Made Structures

Migratory bats are known to die from accidents with human-made structures during migration. They are sometimes found dead after colliding with buildings, communication towers, and aircraft.[35] However, unlike the situation with migratory songbirds that collide with buildings and communication towers in very large numbers during migration periods,[36] the number of migratory bats encountered in such situations is often very low. For example, in the few historical reports involving bat collisions with tall structures, hundreds of birds of many different species were typically encountered along with the bats, yet bat fatalities rarely numbered more than two to three individuals per collision incident.[37] In fact, the total number of bats reported to have died at human-made structures in all published accounts prior to the past decade was less than 200 individuals,[38] and this total number included two long-term studies—eight and twenty-five years—that specifically searched for bat fatalities.[39] Prior to the discovery of bat fatalities at wind turbines in the 1990s, collision mortality of bats with human-made structures was not an obvious conservation issue.

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*Natural History of the Red Bat (*Lasiurus borealis*) in Indiana*, 75 PERIODICUM BIOLOGORUM 155, 157–58 (1973) (reporting bat deaths caused by predation from blue jays and a hailstorm).

35 Paul M. Cryan & Adam C. Brown, *Migration of Bats Past a Remote Island Offers Clues Toward the Problem of Bat Fatalities at Wind Turbines*, 139 BIOLOGICAL CONSERVATION 1, 6 (2007); Suzanne C. Peurach et al., *A Decade of U.S. Air Force Bat Strikes*, 3 HUM.-WILDLIFE CONFLICTS 199, 199 (2009).

36 *See generally* MICHAEL L. AVERY ET AL., U.S. FISH & WILDLIFE SERV., AVIAN MORTALITY AT MAN-MADE STRUCTURES: AN ANNOTATED BIBLIOGRAPHY (1978) (documenting observations of bird casualties during migration).

37 *See* Michael Avery & Tom Clement, *Bird Mortality at Four Towers in Eastern North Dakota—Fall 1972*, 4 PRAIRIE NATURALIST 87, 90 (1972); Robert L. Crawford & W. Wilson Baker, *Bats Killed at a North Florida Television Tower: A 25-Year Record*, 62 J. MAMMALOGY 651, 651 (1981); Albert F. Ganier, *Bird Casualties at a Nashville T-V Tower*, 33 MIGRANT 58, 59 (1962); Donald W. Janes, *Echo-Location Failure and a Late Seasonal Record for the Red Bat in Kansas*, 62 TRANSACTIONS KAN. ACAD. SCI. 263, 264 (1959); Robert Overing, *The 1935 Fall Migration at the Washington Monument*, 48 WILSON BULL. 222, 224 (1936); John K. Terres, *Migration Records of the Red Bat,* Lasiurus borealis, 37 J. MAMMALOGY 442, 442 (1956) (recording the deaths of red bats and birds that struck the Empire State Building in New York City); Robert M. Timm, *Migration and Molt Patterns of Red Bats,* Lasiurus borealis *(Chiroptera: Vespertilionidae) in Illinois*, 14 BULL. CHI. ACAD. SCI. 1, 2 (1989) (noting fifty dead red bats found below the windows at a downtown Chicago convention center between 1979 and 1987); Richard G. Van Gelder, *Echo-Location Failure in Migratory Bats*, 59 TRANSACTIONS KAN. ACAD. SCI. 220, 220 (1956) (describing numbers of red bats and birds killed by striking a television tower in Topeka, Kansas).

38 *See* sources cited *supra* note 37 (historical accounts cataloguing bat deaths prior to 1990 for a total of less than 200).

39 Timm, *supra* note 37, at 2 (eight-year study recording 50 bat fatalities); Crawford & Baker, *supra* note 37, at 651 (twenty-five year study recording 54 bat fatalities)

IV. WIND TURBINES: AN EMERGING THREAT TO BAT MIGRATIONS

Beginning in the mid 1990s, biologists monitoring industrial-scale wind turbines for bird fatalities began reporting bat carcasses found beneath wind turbines.[40] Given the lack of prior evidence for frequent collisions of bats with human-made structures, bat researchers were intrigued by these new reports. In autumn of 2003 and 2004, an unprecedented number of bat fatalities at wind facilities in the Appalachian Mountains raised concerns with conservationists and bat researchers, who had never known or anticipated such high fatality rates.[41] For example, between 1500 and 4000 bats were estimated to have died at a single wind energy site during 2004,[42] which far exceeded the total number of bats ever reported to have died from collisions with other human-made structures.[43]

A. Documenting Bat Fatalities at Wind Energy Sites

Since 2004, unprecedented rates of bat fatalities have been documented at multiple wind energy sites across the United States and Canada,[44] as well as in several European countries.[45] In the United States, bat fatality rates at turbines are variable across sites and regions. Despite standardized and well-validated methods for measuring and comparing fatality rates across sites rarely being employed, estimates to date for individual wind energy sites range from just below one bat per installed megawatt per year (bats/MW/yr)[46] to as high as 70 bats/MW/yr.[47] These fatality rates for bats generally exceed the fatality rates of migratory songbirds at wind turbines,[48]

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40 The first report on bat deaths at wind turbines was published in 2003. Gregory D. Johnson et al., *Mortality of Bats at a Large-Scale Wind Power Development at Buffalo Ridge, Minnesota*, 150 AM. MIDLAND NATURALIST 332, 332 (2003).

41 Justin Blum, *Wind Turbines Killing Thousands of Bats*, WASH. POST, Jan. 1, 2005, at A01.

42 *Id.*

43 *See supra* notes 38–39 and accompanying text.

44 *See* Edward B. Arnett et al., *Patterns of Bat Fatalities at Wind Energy Facilities in North America*, 72 J. WILDLIFE MGMT. 61, 63 tbl.1 (2008) (displaying estimates of mean bat fatalities per turbine and per megawatt of wind energy produced in North America).

45 *See* LUÍSA RODRIGUES ET AL., EUROBATS, UNITED NATIONS ENV'T PROGRAMME, GUIDELINES FOR CONSIDERATION OF BATS IN WIND FARM PROJECTS 9 (2008).

46 *See* Arnett et al., *supra* note 44, at 63 tbl.1. The typical land-based turbine being installed at the time of this writing has an installed capacity of one to two MW. *See* Paul M. Cryan & Robert M.R. Barclay, *Causes of Bat Fatalities at Wind Turbines: Hypotheses and Predictions*, 90 J. MAMMALOGY 1330, 1330 (2009).

47 Arnett et al., *supra* note 44, at 63 tbl.1.

48 *See* Robert M.R. Barclay et al., *Variation in Bat and Bird Fatalities at Wind Energy Facilities: Assessing the Effects of Rotor Size and Tower Height*, 85 CANADIAN J. ZOOLOLOGY 381, 384 (2007) (noting bat fatality rates that exceed those for birds with increasing turbine tower height); Cryan & Barclay, *supra* note 3, at 1330–31; William P. Kuvleksy, Jr. et al., *Wind Energy Development and Wildlife Conservation: Challenges and Opportunities*, 71 J. WILDLIFE MGMT. 2487, 2490 (2007); Craig K.R. Willis et al., *Bats Are Not Birds and Other Problems with Sovacool's (2009) Analysis of Animal Fatalities Due to Electricity Generation*, 38 ENERGY POL'Y 2067, 2068 (2010) ("Numbers of bats killed per species [at wind turbines] are much higher than for birds . . . .").

and far exceed any documented natural or human-caused sources of mortality in the affected species of bats.[49] Some large wind energy facilities (e.g., 100–300 MW) are estimated to have fatality rates of 10–20 bats/MW/yr,[50] which means that single wind energy facilities are causing the deaths of thousands of bats per year. With approximately 40,000 MW of turbines currently installed in the United States[51] and Canada,[52] and an average published bat fatality rate of 11.6 bats/MW/yr,[53] more than 450,000 bats may already perish at turbines each year in North America. This number might even be an underestimate due to problems with earlier fatality estimation equations[54] and because bat fatality rates appear to be increasing with deployment of larger turbines.[55] Furthermore, certain species of bats are more susceptible to turbines than others.[56]

B. Emerging Patterns of Bat Mortality at Wind Energy Sites

Startling patterns are emerging from the available information on bat fatalities at wind turbines. Foremost among these patterns is that only three species of migratory tree bats comprise the majority of fatalities documented to date.[57] Hoary bats compose about half of all documented fatalities in North America, and eastern red bats and silver-haired bats each compose about one-fifth of all fatalities.[58] Substantial numbers of migratory cave-dwelling Brazilian free-tailed bats (*Tadarida brasiliensis*) are also found beneath turbines in the southwestern parts of North America,[59] but data from

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49 Paul M. Cryan et al., *Wing Pathology of White-nose Syndrome in Bats Suggests Life-Threatening Disruption of Physiology*, 8 BMC BIOLOGY, art. no. 135, Nov. 11, 2010, *available at* http://www.biomedcentral.com/content/pdf/1741-7007-8-135.pdf.

50 Arnett et al., *supra* note 44, at 63 tbl.1, 77 app. B.

51 As of September 30, 2010, the United States had 36,698 MW of installed wind power capacity. NAT'L RENEWABLE ENERGY LAB., U.S. DEPT. OF ENERGY, UNITED STATES—CURRENT INSTALLED WIND POWER CAPACITY (MW) (2010), *available at* http://www.windpoweringamerica.gov/pdfs/wind_maps/installed_capacity_current.pdf.

52 As of December 2010, Canada had 4008 MW of installed wind power capacity. CANADIAN WIND ENERGY ASSOC., POWERING CANADA'S FUTURE, *available at* http://www.canwea.ca/pdf/Canada%20Current%20Installed%20Capacity_e.pdf.

53 Arnett et al., *supra* note 44, at 63 tbl.1.

54 *See* Manuela M. P. Huso, *An Estimator of Wildlife Fatality from Observed Carcasses*, 22 ENVIRONMETRICS (forthcoming 2011) (manuscript § 5.4).

55 *See* Barclay et al., *supra* note 48, at 384 (noting that bat fatalities increase "exponentially" as turbine height increases).

56 *See* Arnett et al., *supra* note 44, at 64 ("Of the 45 species of bats that occur north of Mexico, 11 were reported killed at wind energy facilities." (citation omitted)).

57 *Id.* at 64 tbl.2.

58 *Id.* (reporting percentages of recorded North American bat fatalities: 41% hoary bat; 21% eastern red bat; 15% silver-haired bat).

59 *See* Martin D. Piorkowski & Timothy J. O'Connell, *Spatial Pattern of Summer Bat Mortality from Collisions with Wind Turbines in Mixed-Grass Prairie*, 164 AM. MIDLAND NATURALIST 260, 266 (2010); *see also* Amanda Miller, Patterns of Avian and Bat Mortality at a Utility-Scaled Wind Farm on the Southern High Plains (August 2008) (unpublished M.S. thesis, Texas Tech University), *available at* http://www.batsandwind.org/pdf/Bibliography%20docs/

most sites within their range are not available.[60] Although fatalities of migratory tree bats have been recorded at almost every wind energy site that has been monitored for bats, the factors influencing fatality rates remain unclear.[61] It initially appeared that fatality rates were high only on the forested ridges of the Appalachian Mountains, but then sites with high fatality rates were also discovered in flat agricultural landscapes in other parts of North America.[62] Studies at sites in North America have not found any consistent relationships between local landscape features and fatality rates, nor do we have a clear understanding of the regions or types of habitats where fatalities are most likely to occur.[63] Thus, we do not yet know how to identify and avoid high-risk sites for bats and wind energy. Most fatalities of bats at turbines typically begin in about mid-July, increase in frequency until about mid-September, then decline into October—a period that coincides with their autumn migration and the beginning of their mating periods.[64] Over the course of a few short years, we are consistently seeing migratory tree bats die in unprecedented and unexpected numbers at wind turbines during their autumn migration.

C. Impacts on Migratory Bat Populations

Prior to the issue of bat fatalities at wind turbines, there were no clear or quantifiable human-induced threats to entire populations of migratory tree bats. It is possible that wind turbines may be causing, or will eventually cause, unsustainable population declines in some of the affected species. The population sizes of migratory tree bats are unknown because of their cryptic habits and limitations in the ways that biologists estimate the number of animals in a population,[65] which makes it unlikely that methods for accurately measuring their population sizes will become available in the near future.[66] Thus, there is little information with which to assess how

Miller_Amanda_Thesis.pdf (describing carcass searches below wind turbines at a facility in the Texas panhandle that uncovered mostly Brazilian free-tailed bats).

60 *See infra* Part V.B.

61 *See* Arnett et al., *supra* note 44, at 68 (offering explanations of factors influencing increased bat fatalities); Kunz et al., *supra* note 1, at 317–18 (pondering possible explanations for bat fatalities caused by wind turbines).

62 Kunz et al., *supra* note 1, at 317 ("[R]elatively large numbers of fatalities have been reported in agricultural regions from northern Iowa and southwestern Alberta, Canada [as well as] in mixed-grass prairie in Woodward County, north-central Oklahoma." (citations omitted)); *id.* at 321 ("A recent study conducted at wind energy facilities in an agricultural region in southwestern Alberta, Canada, unexpectedly found fatality rates comparable to those observed in some forested ridgetops in the eastern US.").

63 Arnett et al., *supra* note 44, at 67–68.

64 *See* Cryan & Brown, *supra* note 35, at 5 fig.2.

65 *See* Willis et al., *supra* note 48, at 2067 (explaining how bat population sizes are poorly understood).

66 *See* Timothy C. Carter et al., *Population Trends of Solitary Foliage-Roosting Bats*, *in* MONITORING TRENDS IN BAT POPULATIONS OF THE UNITED STATES AND TERRITORIES, *supra* note 10,

quickly the current rates of bat fatality at turbines could cause catastrophic population declines and possibly species extinctions. Some might argue that the high rates of tree bat fatalities indicate that there are far more of these animals than previously thought, and that the fatality numbers are proportional to their greater abundance. The logic flowing from this speculation is that their populations are likely large enough to sustain turbine-induced mortality. If true, then all other research methods for detecting migratory tree bats, such as trapping, shooting, or monitoring their echolocation calls, have underestimated the relative abundance of these animals over the past century. For perspective, more hoary bats are estimated to die at certain individual wind energy facilities in the United States in two to three years[67] than have ever been collected and preserved as scientific study specimens in the museums of the Americas.[68] In some parts of the country, bat researchers who only rarely catch hoary bats in the wild can now walk beneath turbines at certain wind energy facilities during autumn and find more dead hoary bats on the ground in a few weeks than they have caught during their entire careers. A more haunting possible explanation for such high numbers of migratory tree bats at turbines is not that more of them are out there than other bats but rather that something about their behavior puts them at risk of collision.[69] The seasonality of fatalities and the species of bats involved suggest that something about their common behaviors during migration might be the key to their vulnerability.

V. THE IMPORTANCE OF SCIENTIFIC RESEARCH INTO BAT MORTALITY AT TURBINES

Many possible explanations have been proposed for explaining why bats, and particularly migratory tree bats, are so susceptible to wind turbines.[70] These explanations range from random collisions with blades that bats do not perceive as they fly past during migration to being attracted by turbines for feeding or mating opportunities.[71] Although determining the proximate causes of bat fatalities at wind turbines may seem like an academic pursuit, it may be essential for two primary reasons. First, knowing whether turbines are killing small numbers of individuals from

at 41, 46 (describing how population trends of foliage-roosting bats "will remain unknown" until methods of quantitative analysis are developed).

67 For example, take the estimated fatality rate per MW for the Maple Ridge Wind Farm (14.9 bats/MW/yr), Arnett et al., *supra* note 44, at 63 tbl.1, multiply by the percentage of hoary bats recovered at that site (46%), *id.* at 64 tbl.2, then multiply that product by the installed capacity of the site (322 MW), CARL J. GEORGE, CAPITAL REGION ENERGY FORUM, MAPLE RIDGE WIND FARM – 12 JUNE 2009, *available at* http://www.capitalregionenergyforum.org/pdfs/Maple%20Ridge%20Wind%20Farm%206_09.pdf, for a total estimate of 2207 hoary bats per year.

68 The total number of hoary bat specimens found in a broad survey of scientific museum collections was 3217. Paul M. Cryan, *Seasonal Distribution of Migratory Tree Bats (*Lasiurus and Lasionycteris*) in North America*, 84 J. MAMMALOGY 579, 581 (2003).

69 Cryan & Barclay, *supra* note 3, at 1336.

70 *Id.* at 1332; Kunz et al., *supra* note 1, at 317–19.

71 *See* Cryan & Barclay, *supra* note 3, at 1332 tbl.1 (listing possible hypotheses for explaining bat fatalities at wind turbines).

large populations (e.g., random collisions) or large numbers of individuals from potentially smaller populations (e.g., attraction) will help gauge the gravity of the situation and need for conservation measures. If turbines are attracting bats, then conservation actions may need to be implemented sooner than if turbines are not attracting bats.[72] If turbines attract and kill bats during migration, then they are not only acting as barriers to migration and disrupting necessary migratory connectivity but also acting as population 'sinks' exactly where and when large proportions of affected populations could be concentrating in space and time—in geographic 'bottlenecks' where conditions (e.g., wind and insect availability) for migration are most favorable. Second, without knowing the exact reasons why bats are susceptible to turbines, researchers trying to find ways of minimizing fatalities will continue to grope in the dark for effective solutions.[73] Research into the causes of bat fatalities at wind turbines seems to be an important step toward ensuring the well-being of migratory bat populations on a continent of ever-increasing wind energy development.

A. Gaps in Legal Protection

Considerable challenges exist on the path toward better understanding and conserving migrant bats threatened by wind turbines. First and foremost, none of the bat species currently known to be affected in large numbers by wind turbines are protected by federal conservation laws, such as the Endangered Species Act (ESA),[74] or legislation pursuant to international treaties, such as the Migratory Bird Treaty Act.[75] An exception may be the Hawaiian hoary bat (*Lasiurus cinereus semotus*), a subspecies occurring only on the Hawaiian Islands listed as endangered under the ESA.[76] Although about 63 MW of wind capacity has already been installed or is under construction in Hawaii as of September, 2010,[77] the risk turbines pose to the Hawaiian hoary bat, which is an altitudinal migrant,[78] has not been scientifically assessed.

Prior to the discovery of large numbers of bats beneath wind turbines in the continental United States and Canada, there was no reason to suspect

72 *Id.* at 1338.

73 *See id.*

74 Endangered Species Act of 1973, 16 U.S.C. §§ 1531–1544 (2006).

75 Migratory Bird Treaty Act, 16 U.S.C. §§ 703–712 (2006); O'Shea & Bogan, *supra* note 10, at 3 tbl.1; Theodore J. Weller et al., *Broadening the Focus of Bat Conservation and Research in the USA for the 21st Century*, 8 ENDANGERED SPECIES RES. 129, 141 (2009).

76 *See* U.S. FISH & WILDLIFE SERV., RECOVERY PLAN FOR THE HAWAIIAN HOARY BAT (*LASIURUS CINEREUS SEMOTUS*) 8 (1998), *available at* http://ecos.fws.gov/docs/recovery_plans/1998/980511b.pdf.

77 Am. Wind Energy Ass'n, U.S. Wind Energy Projects—Hawaii, http://archive.awea.org/projects/projects.aspx?s=Hawaii (last visited Apr. 10, 2011).

78 Theresa Menard, Activity Patterns of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) in Relation to Reproductive Time Periods 86 (Dec. 2001) (unpublished M.S. thesis, University of Hawai'i) (on file with author).

that bat populations could be imperiled so rapidly by human actions. Four species and three subspecies of bats in the United States are listed as endangered under the ESA, all of which except the Hawaiian hoary bat form large aggregations in caves and were historically known or believed to be at risk of extinction because of observed declines at large colonies and known human disturbance of large roosting groups.[79] With the exception of the Hawaiian hoary bat, there is no precedent to follow in the United States for protecting bat species with mostly uncharacterized habitats, that do not form large colonies, and may have population sizes that are unknown or unknowable in the near future.

B. Gaps in Monitoring and Conservation at Wind Energy Sites

Because most bats are not protected by law, there is no comprehensive, continental-scale mandate to either monitor or take conservation actions toward bat fatalities at wind turbines. Much of the wind energy development that has occurred to date in the continental United States has been on private lands,[80] where permitting and regulation of wind facilities usually occurs at the county or state administrative levels.[81] Some local government agencies require monitoring and public release of resulting data, while others do not.[82]

Although many wind energy companies conduct surveys for wildlife fatalities at turbines, including bats, they do not regularly make data available to the public.[83] Among the patchy fatality data sets that have become available, informative patterns have been observed, such as the predominance of migratory tree bats killed during autumn migration and mating periods and sometimes a bias toward adult males.[84] However, the

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79 O'Shea & Bogan, *supra* note 10, at 2; *see also* U.S. FISH & WILDLIFE SERV., *supra* note 76, at 10, 12 (describing life characteristics and habitat of the Hawaiian hoary bat).

80 Reed Elizabeth Loder, *Breath of Life: Ethical Wind Power and Wildlife*, 10 VT. J. ENVTL. L. 507, 512 (2009). For a rough illustration of where wind facilities are located vis-á-vis federal public lands and Indian reservations, compare U.S. GEOLOGIC SURVEY, DEP'T OF INTERIOR, FEDERAL LANDS AND INDIAN RESERVATIONS (2005), *available at* http://www.nationalatlas.gov/printable/images/pdf/fedlands/fedlands3.pdf, which depicts federal public lands and Indian reservations, with U.S. DEP'T OF ENERGY, 2009 WIND TECHNOLOGIES MARKET REPORT 9 (2009), *available at* http://www1.eere.energy.gov/windandhydro/pdfs/2009_wind_technologies_market_report.pdf, which depicts locations of wind power facilities.

81 *See* Helle Tegner Anker et al., *Wind Energy and the Law: A Comparative Analysis*, 27 J. ENERGY & NAT. RESOURCES L. 145, 154–55, 161–62 (2009) (describing sub-national jurisdictional controls over wind energy development in countries with federal systems); Melanie McCammon, *Environmental Perspectives on Siting Wind Farms: Is Greater Federal Control Warranted?*, 17 N.Y.U. ENVTL. L.J. 1243, 1258 (2009) ("Most wind power development in the United States is on private land, and so is regulated by the states.").

82 *See, e.g.*, GREG JOHNSON ET AL., AVIAN AND BAT MORTALITY DURING THE FIRST YEAR OF OPERATION AT THE KLONDIKE PHASE I WIND PROJECT, SHERMAN COUNTY, OREGON 2 (2003), *available at* http://www.west-inc.com/reports/klondike_final_mortality.pdf.

83 *See* Arnett et al., *supra* note 44, at 62.

84 *See id.* at 64–65.

information available is of variable quality and many areas are under-represented, making it difficult to ascertain the geographic extent and magnitude of bat fatalities at wind energy sites or the underlying reasons for these fatalities. For example, the top state for wind energy development is Texas, where bat diversity is also among the highest in the country, yet there is very little data available from bat monitoring efforts at wind turbines in Texas.[85] Nonetheless, some wind energy companies are actively engaged in research efforts to understand and establish the underlying causes of bat fatalities at wind turbines and help find ways to understand the causes of collisions and minimize their impacts.[86]

C. Benefits of Research on Bat Mortality at Wind Turbines

One of the proven benefits of research directed toward bats and wind turbines is the recent discovery of what may potentially be a partial solution to the problem. Studies in Canada and the United States have independently shown that curtailment—preventing turbine blades from turning during relatively low wind speeds (less than five or six meters per second) at night during late-summer and autumn—can reduce bat fatalities by as much as forty to ninety percent.[87] The reason why this technique works to reduce bat fatalities is still unclear, but its implementation stems from the observation that most bat fatalities at turbines were occurring on late-summer and autumn nights with low wind speeds. Although curtailment still needs to be tested under a wider range of situations, it may eventually be validated as an effective way to minimize bat fatalities.

However, it remains to be seen whether or not a technique such as curtailment will be implemented to a degree that would meaningfully reduce the threat of wind turbines as widespread obstacles disrupting migrations of bats in the United States and Canada. The economic costs associated with curtailing turbine operation—although likely to be low relative to total energy production[88]—the lack of accurate measurements on the impact of wind turbines on overall bat populations, and the absence of requirements for wind facility operators to minimize fatalities of unprotected bat species all pose considerable challenges to what is currently our only potential solution to the problem.

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85 *Id.* at 72.

86 *See, e.g.*, Press Release, Bat & Wind Energy Coop., Researchers Seek to Reduce Bat Deaths at Wind Turbines (Oct. 14, 2008), *available at* http://www.batsandwind.org/pdf/BWEC%20Curtailment%20Press%20Release10-14.pdf.

87 *See* Edward B. Arnett et al., *Altering Turbine Speed Reduces Bat Mortality at Wind-Energy Facilities*, 9 FRONTIERS ECOLOGY & ENV'T (forthcoming 2011); Erin F. Baerwald et al., *A Large-Scale Mitigation Experiment to Reduce Bat Fatalities at Wind Energy Facilities*, 73 J. WILDLIFE MGMT. 1077, 1079 (2009).

88 *See* EDWARD B. ARNETT ET AL., EFFECTIVENESS OF CHANGING WIND TURBINE CUT-IN SPEED TO REDUCE BAT FATALITIES AT WIND FACILITIES: FINAL REPORT 25 (2010), *available at* http://www.iberdrolarenewables.us/pdf/casselman-bats/.

VI. CONCLUSION

Fatalities of migratory bats at wind turbines have been unexpected and unprecedented. There is no evidence of human-induced impacts to the affected bat species that are of similar magnitude to mortality at turbines. Simply put, we have never before seen anything like fatalities of migratory bats at wind turbines and we now have reason to suspect that industrial wind turbines may threaten the well-being of at least three or more migratory bat species in North America.

An analogous situation to turbine disruption of bat migration is the problem of bird fatalities at lighted communication towers.[89] In the latter case, migratory songbirds are attracted to certain types of lights used on tall communication towers.[90] The mandate to protect these songbird migrants under the Migratory Bird Treaty Act[91] helps propel efforts to understand and then address the problem, first by establishing the link between tower lights and fatality rates through research, then by implementing wide-scale changes across an entire industry to minimize fatalities.

In contrast to North America, all species of bats in Europe are protected under the European Union Habitats Directive[92] and even more specifically under the Agreement on the Conservation of Populations of European Bats (EUROBATS).[93] It remains to be seen whether such legal protection will influence the implementation of wide-scale research and conservation measures directed toward migratory populations of European bats being detrimentally affected by turbines.

The story of bats and wind turbines highlights the importance of proactive measures to ensure the health and well-being of vulnerable wildlife populations before or soon after unexpected threats arise and quickly take their toll. Understanding and anticipating such problems depends on a combination of scientific research and a mandate for vigilance. To be prepared is half the battle, and a legal framework for protecting *all* migratory wildlife may be the type of foresight needed to help drive scientific advances that will allow us to better predict and deal with emerging threats to migratory wildlife before they become intractable.

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89 *See* AVERY ET AL., *supra* note 36, at 100.

90 *See* Joelle Gehring et al., *Communication Towers, Lights, and Birds: Successful Methods of Reducing the Frequency of Avian Collisions*, 19 ECOLOGICAL APPLICATIONS 505, 511–12 (2009).

91 *See* Migratory Bird Treaty Act, 16 U.S.C. § 703(a) (2006).

92 RODRIGUES ET AL., *supra* note 45, at 7.

93 Agreement on the Conservation of Bats in Europe arts. I, III, Dec. 4, 1991, 1863 U.N.T.S. 101, *available at* http://treaties.un.org/doc/Publication/UNTS/Volume%201863/v1863.pdf.