FALL 2019 • REPORT NO. 21

ISSUES IN ECOLOGY

PUBLISHED BY THE ECOLOGICAL SOCIETY OF AMERICA

IMPACTS TO WILDLIFE OF WIND ENERGY SITING AND OPERATION IN THE UNITED STATES

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We first describe estimates of bird and bat collision mortality and assessments of population-level effects.

BIRD AND BAT FATALITIES AT LAND-BASED WIND ENERGY FACILITIES

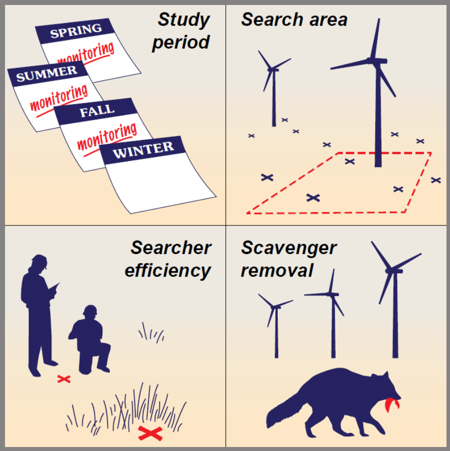
Fatalities of birds and bats from collisions with wind turbines have been documented at nearly every wind facility where studies have been conducted, and possibly the most commonly asked question about wind energy impacts on wildlife is—how many fatalities are there?

National average adjusted fatality rates *(as defined in Box 2)* reported in recent peer-reviewed national reviews vary from approximately three to six birds and four to seven bats per MW of installed wind energy capacity per year. The range of reported fatality rates can vary substantially among projects both within and among geographic regions. For example, reported adjusted fatality rates of small passerines vary across avifaunal regions in the U.S. ranging from about 1.2 to 1.4 fatalities per MW per year in northern forests, to 2.6 to 3.8 in the eastern U.S.[11] Some of the highest bat fatality rates have been reported at projects in eastern forests and the forest-agricultural matrix

BOX 2. ESTIMATING BIRD AND BAT COLLISION FATALITIES AT WIND ENERGY FACILITIES

Collision fatalities are estimated based on carcass searches conducted under operational wind turbines. Raw counts from searches underestimate the number of collision fatalities and must be adjusted for four primary sources of detection error described below. Standardized protocols are widely used to estimate these four sources of error and develop less biased estimates of collision fatalities.

- **Study period.** Many fatality-monitoring studies in the U.S. are not conducted during the winter because the activity of many species is reduced due to hibernation or migration; nonetheless, fatalities can occur. To compare annual fatality rates, estimates for some studies must be extrapolated beyond their period of monitoring.
- **Search area.** Search plots are usually centered on an individual wind turbine, but often terrain and vegetation cover prevent searching of the entire plot. Models of carcass densities at different distances from the turbine can be used to estimate the fraction of carcasses landing outside the search area, allowing researchers to adjust for unsearched area. Typically, only a sample of turbines is searched requiring extrapolation to the entire facility, although variation among turbines could occur.
- **Scavenger removal.** Animal scavengers can remove carcasses from the search area before searchers can find them. Bird and bat carcasses are placed within search plots and checked periodically over a set time period to determine how long a carcass will remain present and recognizable by a searcher. Results are used to estimate the probability of a carcass persisting between one carcass search and the next.
- **Searcher efficiency.** Searcher efficiency measures the proportion of carcasses present at the time of a search that a searcher can find. Carcasses of different sizes are placed within areas assumed to differ in detection rates. The proportion of placed carcasses found by searchers estimates searcher efficiency for combinations of carcass size and visibility class.



Box 2 Figure 1. Sources of detection error when estimating fatalities from collisions with wind turbines.

Fatality estimators: These are statistical equations that calculate an estimate of the total number of fatalities from raw carcass counts and information from trial carcasses used to estimate the different sources of detection error. A new generalized estimator (Gen-Est) uses data collected during carcass searches and estimates of detection rates to more accurately estimate the number of fatalities and to provide an accurate measure of precision associated with that estimate.

Adjusted fatality estimates are reported as fatalities per turbine or per MW installed capacity per season or year and are often reported for different groups, such as small birds, raptors, or bats, each of which may have different searcher efficiencies, scavenger removal rates, and spatial and temporal distributions. Possible sources of errors generally not accounted for in calculating fatality estimates include background fatalities (birds and bats dying from causes other than collisions) and fatally injured birds and bats that are able to fly beyond the limits of the search area.

POST-CONSTRUCTION BIRD AND BAT FATALITY MONITORING FOR ONSHORE WIND ENERGY FACILITIES IN EMERGING MARKET COUNTRIES

Good Practice Handbook and Decision Support Tool

European Bank
for Reconstruction and Development

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1. UNDERSTANDING POST-CONSTRUCTION FATALITY MONITORING

Impacts on wildlife caused by onshore wind energy facilities (WEFs) have been well documented for decades and include collision, habitat modification, displacement, and barrier effects (Allison et al. 2019; Drewitt and Langston 2006; Gove et al. 2013; Katzner et al. 2019; Perrow 2017; Schuster, Bulling, and Köppel 2015). Of these, collisions of birds and bats with turbines is the most universal, resulting in fatalities and requiring the most attention (Arnett et al. 2016; Marques et al. 2014; Thaxter et al. 2017). Overhead power lines (OHLs) associated with WEFs[1] exacerbate risks to birds through collision and electrocution (Jenkins, Smallie, and Diamond 2010; Lehman, Kennedy and Savidge 2017; Martín Martín et al. 2021 Prinsen et al. 2011). OHL collision risk to bats is poorly understood but studies indicate that most bat species are unlikely to regularly collide with these types of structures (e.g., Mogdans, Ostwald, and Schnitzler 1988; Vanderelst, Holderied, and Peremans 2015). The risk of OHL electrocution to larger bat species has been demonstrated (Chouhan and Shrivastava 2019; Rajeshkumar, Raghunathan, and Venkataraman 2013; Tella et al. 2020).

As the wind energy sector expands globally, the potential for site-specific and cumulative impacts on birds and bats will continue to increase. In developed markets, the risks and impacts from WEFs and the efficacy of associated mitigation measures are generally well understood, and regulations for biodiversity protection are often in place. In many emerging market countries,[2] the industry is typically at an earlier stage of development, and regulatory processes may not require adequate biodiversity safeguards at project sites. In these situations, the potential for adverse impacts on susceptible wildlife populations to go unchecked is significant. This concern is amplified as species data in emerging market countries are typically scarcer than in developed markets, and the extent of threatened biodiversity is comparatively higher.[3,4]

The impacts associated with WEFs are highly unpredictable, even when robust pre-construction baseline survey results are available (Ferrer et al. 2012; Hein, Gruver, and Arnett 2013; Solick et al. 2020). Although rigorous pre-construction baseline studies are necessary to characterize risks, post-construction fatality monitoring (PCFM) is the only way to understand the actual collision impacts of WEFs on birds and bats. Implementing a robust PCFM program during the operational phase of a WEF is therefore critical for effective management and mitigation of biodiversity impacts.

1.1 What is PCFM?

PCFM generally comprises:

- Searches conducted during the operations phase of a project to search for evidence of bird and bat fatalities at a WEF
- Field trials to estimate the number of fatalities missed during searches either because they were removed before the next carcass search (e.g., by scavenging animals) or because they were overlooked by searchers
- Analyses to quantify bird and bat fatality rates at the WEF using fatality estimation software

[1] OHLs associated with WEFs are referred to as WEF-associated OHLs in this Handbook.

[2] For the purposes of this Handbook, "emerging market" countries are those considered to be low-income, lower-middle income, and upper-middle-income economies, according to the World Bank Country Classifications.

[3] For example, of the 100 globally threatened bird and bat species predicted to be at the highest risk of collision with wind turbines, 82 and 88 percent, respectively, are in the Global South, based on data in Thaxter et al. (2017).

[4] See also, Schmeller et al. (2017) which highlights the relative scarcity of data from biodiversity-rich regions compared to North America and Europe, and Frick, Kingston and Flanders (2020), which highlights this disparity for bat populations specifically.

Despite the focus on fieldwork and analysis, PCFM is not meant to be an exercise in data collection for its own sake; it is intended to inform implementation of a Biodiversity Management Plan (BMP) during the operations phase of a WEF, namely the effectiveness of mitigation, as prescribed in the relevant Environmental and Social Impact Assessment (ESIA) or by government consenting or licensing authorities. During the operations phase of a WEF, PCFM data serve as the backbone for adaptive management (see Section 6), decision making, and demonstration of compliance with environmental requirements of governments or financiers (see Section 1.5).

A well-designed PCFM program will document the range of species occurring as fatalities, the scale of mortality, and reveal spatial and temporal fatality patterns all of which will allow the WEF developer[5] to effectively manage bird and bat collision and electrocution risk.

1.2 Why Focus on PCFM?

A unique aspect of biodiversity management at a WEF is that the focus of monitoring and mitigation is during the *operations phase*, rather than the *construction phase*, and the impacts are primarily in the *air space*. This combination of factors could make the screening of biodiversity risk for this sector difficult for financial institutions with large portfolios. For the wind energy sector, the condition of the terrestrial environment, no matter how modified, is not an appropriate indicator of risk. PCFM results provide the only quantitative basis for measuring the actual impacts of WEFs on birds and bats, and although practical advice is available on avoiding and minimizing impacts following the mitigation hierarchy[6] (e.g., Bennun et al. 2021; Rodrigues et al. 2015), there remains a need for a globally informed practitioners handbook to guide the process for monitoring and evaluating the scale of those impacts in a credible, robust manner during the operations phase of a project.

PCFM practice varies considerably between regions, especially in emerging market countries, where guidance may be limited or non-existent. Although PCFM is essential to understanding the impacts of operational WEFs, if not conducted following good international industry practice (GIIP), it could lead to impacts being underestimated or overestimated. As wind energy development is expanding rapidly, implications for entire landscapes are considerable. Although wind energy is regarded as green energy, impacts can be significant (e.g., Frick 2017), and without a GIIP-aligned

Black Harrier (*Circus maurus*). Photo: Chris Van Rooyen

5 The term "developer" is used to refer to the wind energy company that owns the WEF. It is not only intended to reference early-stage project development but is used generically to refer to the entity (company) ultimately responsible for the wind power project, including during the entirety of operations or any part of them.

6 In alignment with the International Finance Corporation's Performance Standard 1, the mitigation hierarchy is defined as actions taken to anticipate and avoid risks and impacts on the environment or, when avoidance is not possible, minimize and, when residual impacts remain, offset these risks and impacts. The mitigation hierarchy is a central tenet to the environmental and social standards followed by the International Finance Corporation, the European Bank of Reconstruction and Development and *Kreditanstalt für Wiederaufbau*.

3. PCFM: CONCEPTS AND PRINCIPLES

This section provides the conceptual background and building blocks for designing a PCFM study. The focus is on turbine searches, with differences in the design for WEF-associated OHLs presented in Section 3.4. One of the aims of this section is to explain how decision making throughout the design process may affect the precision[16] of PCFM results.

3.1 CORE CONCEPTS

As highlighted in Section 1 of this Handbook, PCFM principally involves:

> Designing, planning, and conducting searches for bird and bat fatalities

> Conducting bias correction field trials

> Calculating fatality rate estimates from the data collected during the previous two activities

The first two activities are covered in this section, and fatality rate estimation is described in Section 5.

Designing and planning a PCFM search program will require the practitioner to be familiar with the following design components:

STUDY DURATION is the number of years that PCFM should be conducted.

TURBINE SAMPLE is the number or proportion of turbines searched for bird and bat fatalities.

SEARCH PLOT SHAPE AND SIZE is the shape and size of the search area at each individual turbine. The search plot may be circular or square and centered on the turbine, or it may consist only of the gravel pad around a turbine, adjacent crane pad, and the road(s) leading up to it.

TRANSECT WIDTH is the spacing between transects walked by searchers within the search plots at each turbine when searching for fatalities.

SEARCH INTERVAL is the time between consecutive fatality searches (sometimes referred to as "search frequency").

[16] Precision refers to the repeatability of a statistical estimate and is usually indicated with a confidence interval (CI). See Section 5 of this Handbook.

Additionally, to derive unbiased fatality rate estimates, the results from a PCFM search program must be corrected to account for the main biases that arise when conducting PCFM fieldwork. To do this the practitioner will need to understand the following bias correction design components:

UNSEARCHED AND UNSEARCHABLE AREA refers to the areas within the fatality fall zone at a sample turbine that are unsearched for some reason, such as being beyond the search plot boundary, or within the search plot but unsafe to search (e.g., steep terrain) or having such complex ground cover that detection would be nearly impossible (e.g., forested areas).

SEARCHER EFFICIENCY TRIALS are field trials used to measure the probability that a searcher will detect a carcass on the ground at the time of a search.

CARCASS PERSISTENCE TRIALS are field trials used to measure the typical amount of time bird and bat carcasses persist on the ground before being removed by scavengers or becoming undetectable because of environmental factors (e.g., flooding, decomposition).

Figure 3.1 illustrates the PCFM design components for fatality searches and bias correction.

Figure 3.1 WEF PCFM design components