A Comment on "Bats Killed in Large Numbers at United States Wind Energy Facilities"

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Widespread reports of bat fatalities caused by wind turbines have raised concerns about the impacts of wind power development. Reliable estimates of the total number killed and the potential effects on populations are needed, but it is crucial that they be based on sound data. In a recent BioScience *article, Hayes (2013) estimated that over 600,000 bats were killed at wind turbines in the United States in 2012. The scientific errors in the analysis are numerous, with the two most serious being that the included sites constituted a convenience sample, not a representative sample, and that the individual site estimates are derived from such different methodologies that they are inherently not comparable. This estimate is almost certainly inaccurate, but whether the actual number is much smaller, much larger, or about the same is uncertain. An accurate estimate of total bat fatality is not currently possible, given the shortcomings of the available data.*

Keywords: convenience sample, accuracy, fatality estimates

The effects of wind turbines on bat populations is an important conservation issue, and a reliable estimate of the total number of bats killed would be useful for making informed research and policy decisions. Hayes (2013) attempted to do this, but numerous errors in his analysis yield an unreliable estimate. With only minor changes, his analysis follows the approach of Cryan (2011): Take the average of the number of bats killed per megawatt (MW) of installed wind capacity reported in an earlier review paper by Arnett and colleagues (2008) and multiply by the total installed capacity in the United States in 2012. Cryan's (2011) analysis and estimate are presented in a single sentence in a 16-page article in a nontechnical law review journal. By contrast, Hayes's (2013) estimate was the primary focus of an entire paper in a peer-reviewed scientific journal and invites scrutiny as science. The scientific errors in the analysis are numerous, the two most serious being that the included sites constituted a convenience sample, not a representative sample, and that the individual estimates from these sites are derived from such different methodologies that they are inherently not comparable.

The analysis crucially hinges on the assumption that the data are "a representative sample of wind energy facilities in the United States [in 2012]" (Hayes 2013, p. 976), because, if this assumption is not met, any estimates calculated are impossible to interpret. The sample described in Hayes's (2013) table 1 is not a representative sample but a convenience sample, with 19 points taken directly from Arnett and colleagues (2008) and 3 additional points that seem to have been arbitrarily selected. Strikingly, one of the three new observations (0.5 bats per MW, from Harper County, Oklahoma) not only represents a site already included in Arnett and colleagues' (2008) list (0.8 bats per MW, from Woodward, Oklahoma), but it represents the same set of sampling data—the smaller estimate being the raw carcass count and the larger being an estimate adjusted for detection bias. Other sites are represented several times in the data, including the Tennessee and Minnesota sites, which appear three times each, and the West Virginia site, which appears twice. Even if the selection of sites were representative, repeated sampling without appropriately accounting for it constitutes pseudoreplication and will almost always lead to bias in the results (Hurlbert 1984).

Arnett and colleagues (2008) made no claim that their sample was representative and explicitly rejected the idea of using their sample to estimate the total number of fatalities nationwide. Instead, they pointed out that fatality rates vary greatly by region. Therefore, to accurately reflect national totals, the representative sample of sites should accurately reflect the distribution of installed capacity nationwide, but it does not. For example, Tennessee, which had only 29 MW installed capacity at a single commercial site in 2012, is represented three times (all measurements from the same site), whereas Texas, with over 400 times the installed capacity

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of Tennessee, is only represented once. In his discussion, Hayes (2013) acknowledged that there appear to be striking regional differences, but his failure to account for the disproportionate representation among regions in his estimate undermines his conclusions.

The reported estimate of fatalities in 2012 is based almost entirely on data collected in 2005 or earlier. In the past decade, the installed capacity in the United States has risen tenfold, and the wind energy industry has changed substantially in ways that affect fatality rates: (a) The newer turbines are larger (turbines of 1.5 MW or larger represented less than 50% of capacity in 2005 but represent more than 90% of current capacity; Wiser et al. 2013; Mark Bolinger, Lawrence Berkeley National Laboratory, Berkeley, California, personal communication, 17 January 2014), (b) the siting criteria for new wind power facilities have changed, and (c) many turbines operate under new guidelines to reduce impacts on wildlife (USFWS 2012). These changes in the wind industry cast considerable doubt about the applicability of older data to current conditions.

Another serious error in the analysis is that the individual observations are not reliably reflective of actual annual fatality rates. Inevitably, many carcasses are missed during searches, and fatality estimates at individual sites strongly depend on both the search protocol and the bias correction used by the researchers. Arnett and colleagues (2008) repeatedly cautioned that estimates were derived from such varying levels of effort and methodologies that they could not be directly compared among studies. Recognizing the impossibility of obtaining reliable estimates of fatality rates from currently available data, Piorkowski and colleagues (2012) named the development of standardized fatality estimators as the number one research priority concerning the potential impact of wind energy development on bird and bat populations. The data used in Hayes's (2013) analysis derive from studies with widely differing search efforts, both temporally and spatially; differing methods for adjusting for imperfect detection; and differing estimators of fatality. Until relatively unbiased methods of estimating fatalities are used at individual sites, reliable estimates of total fatality across the nation will remain elusive (Huso 2011).

Current perception is that policy should be science based, and, to achieve that end, policymakers must rely on scientists to provide them with the best information possible. An accurate estimate of bat fatalities at wind turbines nationwide would require accurate and reliable per-MW fatality estimation procedures that are consistent across different sites, and a sample of sites that appropriately reflects the extant sites. Neither of these is achievable with the current publicly available data. Different methodologies result in different biases, and methodologies differ so widely among sites that estimates from individual sites cannot be compared or combined (Huso 2011); requirements to monitor and to make monitoring results publicly available differ widely among states and regions, so that even a random sample of available data is not certain to be representative of the industry as a whole (Warren-Hicks et al. 2013). Hayes's (2013) estimate is almost certainly inaccurate, but it is uncertain whether the actual number is much smaller, much larger, or about the same. An accurate estimate would be based on data that reflect unbiased estimates of fatality at each site and that are from a set of sites that are selected from among all sites (not simply those whose fatality estimates have been made public) using a statistics-based sampling design. Given the shortcomings of the available data, an accurate estimate of total bat fatality is not currently possible.

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