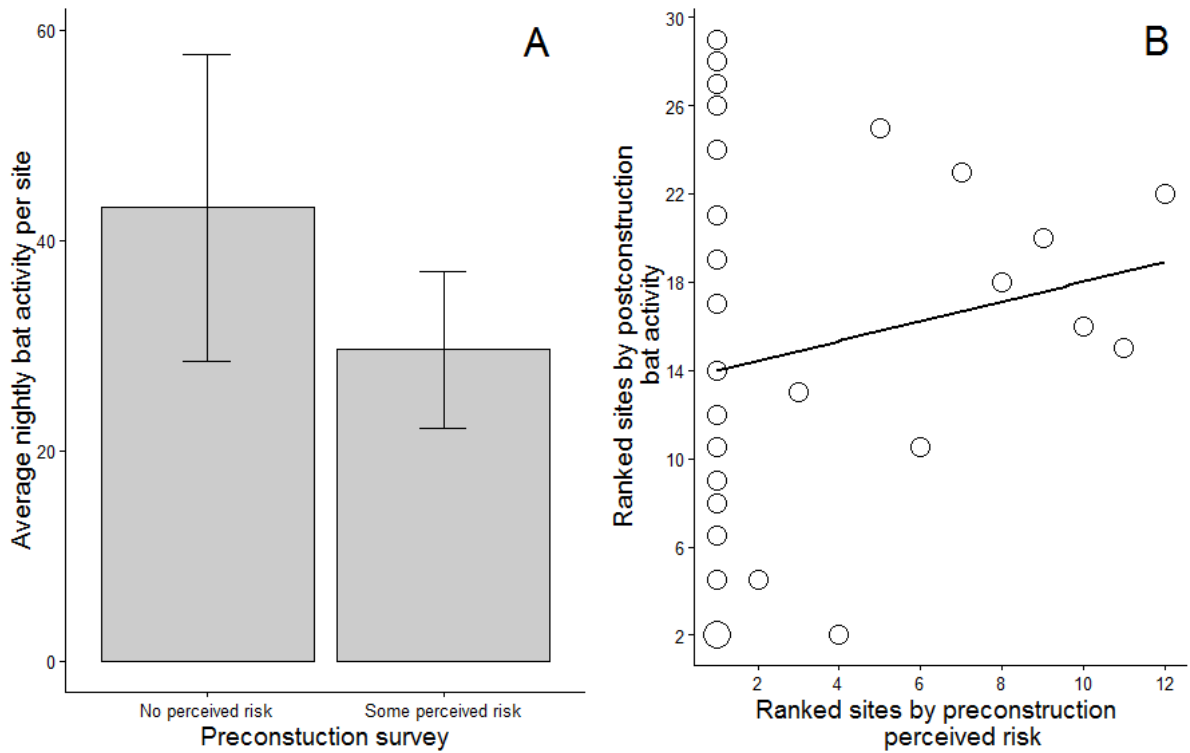


## Supplemental Information: Ecological impact assessments fail to reduce risk of bat casualties at wind farms

Paul R. Lintott, Suzanne .M. Richardson, David J. Hosken, Sophie A. Fensome, and Fiona Mathews

### Supplemental Data Items



**Figure S1.** The relationship between pre-construction assessment of risks to bats and post-construction bat activity, a) the difference in the average nightly activity per site between wind farms where preconstruction surveys perceived different levels of risk. Error bars depict the standard error around the mean. b) the relationship between ranked pre-construction assessment of risk to bats and ranked post-construction bat activity ( $\rho(29) = 0.11$ ,  $p = 0.57$ ). Sites are ranked in ascending order of perceived risk. Circle size is proportional to the number of sites at a particular ranking (range 1 to 2 sites).

**Table S1.** Statement from Environmental Impact Assessments (EIAs) identifying the risk to bats posed by wind energy developments. Statements with a ranking of 1 are examples of EIAs which inferred no risk to bats (n=20). Statements which identified potential risk to bats were ranked in order of severity. Statements have been paraphrased where appropriate to preserve the anonymity of the site

Risk to bats	Rank
We conclude that there are no significant effects on protected species within the proposed development.	1
There will be a negligible effect on protected species and their habitats from this development.	1
There was no bat activity recorded within the site.	1
There is no risk to protected species.	1
Bats not active within study area, but surveys confirmed presence in adjacent areas to the study area	2
A low number of common pipistrelles on the edge of the site indicate that this area is of relatively poor value to bats.	3
Only bats recorded in activity surveys were found at the periphery of the site.	4
Nightly activity varied from 'single passes' to 'several', low impact overall	5
Common and soprano pipistrelles likely to use site, however no other species are likely to present	6
Suitability assessments around each turbine indicated that risk to foraging bats was negligible/low with the exception of 2 areas which were used frequently.	7
Moderate levels of pipistrelle bats were recorded alongside very low levels of <i>Myotis</i> and brown long-eared bats.	8
Results showed that 12 species used this site, however the impact was not considered significant	9
Development likely to impact bats, therefore mitigation to enhance surrounding landscape.	10
Site considered of local conservation value for foraging bats. Mitigation undertaken by placing turbines at least 50m from important foraging areas.	11
High impact on bats due to the loss of hedgerow foraging and commuting habitat. Mitigation undertaken by siting turbines to reduce impacts on bats.	12

## Supplemental Experimental Procedures

### *Methods*

#### *Site selection*

We surveyed 46 wind farms across the UK for bat fatalities as part of a separate field study investigating the impact of wind turbines on bats. We approached local planning authorities and ecological consultants to request copies of EIAs/EcIAs for relevant wind farms. Of the 46 wind farms that were surveyed for bat fatalities, we were able to obtain relevant information from 29. The remaining EIAs/EcIAs were either not available as electronic copies or the location of hard copies were unknown and could not be identified by current owners/operators or local authorities.

#### *Assessing Environmental Impact Assessments*

We searched each EIA/EcIA for any reference to bats and where mentioned the following details were noted: i) surveying methodology, ii) assessment of bat presence and activity within site, iii) risk posed to bat populations, and iv) mitigation strategies undertaken. We classified each site by its perceived risk to bats within two categories; i) no risk to bats, ii) potential risk to bats (Table S1). Sites were ranked based on their perceived risk to bats (the order of the rankings was verified by asking ten bat scientists to independently rank the sites and averaging their results). This ranged from sites where desk-based surveys concluded there was no risk to bats, to sites where bats were only found at the periphery of the development to sites where extensive mitigation strategies were undertaken including situating turbines a substantial distance away from a network of treelines and hedgerows (Table S1). Where mitigation was undertaken we visually assessed these sites using satellite imagery (e.g. distance of turbines from linear features) to ensure that mitigation strategies had been carried out.

#### *Quantifying bat fatalities at wind farms*

We searched six randomly selected turbines at each site for approximately one month between July and October (mean duration 27 days, SD 6). A 100 x 100m square centred on each turbine was searched by a trained dog-handler team following [S1]). The habitat underneath each wind turbine was recorded on a standard pro-forma. Surveying commenced in the early morning to minimise the removal of carcasses by diurnal scavengers (e.g. corvids). The mean search interval was three days (SD 0.03), and each turbine was searched a mean of 11 times. If a carcass was identified, its location and condition were noted and an estimate of the date of death was made. Wing and fur samples were also taken to allow for genetic examination and analysis of stable isotope composition which could provide evidence of whether any migratory bats were killed. Carcasses were identified to species using PCR or by morphometric measurements if genetic identification failed [S2].

The number of individuals found during carcass searches will be an underestimate of the true casualty rate. This is primarily due to three main factors: i) searcher efficiency (the probability that an observer will find a carcass if it is present), ii) carcass removal (by scavengers or decay), and iii) carcasses falling into unsearched areas [S3]. Observer efficiency was tested at the start of searches at each site; the predator removal rate was then estimated by leaving the carcasses in position and checking them each time a search was conducted at the turbine (mean search interval 3 days (SD 0.03) for the duration of the survey (mean duration 27 days). An independent observer placed bat carcasses (mean of six bats per trial;

predominantly *Pipistrellus* spp.) at locations within a 100m x 100m area of similar habitat within the wind farm which was not being searched as part of the study. The bats were dropped from waist height at positions within the grid selected using a random number generator. We then assessed how many carcasses the dog-handler team found with no a-priori knowledge of the number or location of the bats. After completing each observer efficiency trial, we left the carcasses in position to undertake carcass removal trials which allowed us to estimate the rate removals by predation and/or the rate of decay through the duration of the study at each site. Observations only stopped if all carcasses were removed, or when surveying finished at a particular site. We placed location markers away from the carcass itself to ensure that predators were not artificially drawn towards the carcass. It is possible that bat casualties may have fallen into unsearched areas and are unaccounted for in our estimates. However, due to the use of search dogs, there were only very rare occasions when small areas within the designated search areas could not be monitored. In addition, the high levels of observer efficiency and the short inter-search interval provides confidence that major underestimation of true casualty rates is unlikely. We, in common with other researchers [e.g. S4, S5] found that most casualties fell within a short radius of the turbine tower and therefore increasing the size of the search area is likely to have yielded diminishing returns.

Our observations allowed us to estimate the actual number of bats killed at each site after adjusting for differing levels of carcass removal and observer efficiency between sites (e.g. differences in vegetation cover) and across time (e.g. differences in weather conditions). For each site, we then estimated the proportion of bats removed during the mean number of days between searches (inter-search interval). An estimate of the true casualty rate per standard month (30 days) per turbine was computed as follows:

$$Estimate = \frac{n \times Days}{ET \times CRT \times T}$$

$n$  = number of bats found

$T$  = number of turbines searched

$ET$  = proportion of bats found in efficiency trials

$CRT$  = estimate of carcass removal rate

$Days$  = number of days in the month

### *Quantifying bat activity at wind farms*

We placed three full spectrum acoustic bat recorders (SongMeter2 (SM2 and SM2+), Wildlife Acoustics USA)) on either 2m high tripods or on the steps leading up to the turbine at each of the 46 wind farm sites. We programmed each detector to make automatic nightly recordings starting 30 minutes before sunset and ending 30 minutes after sunrise. We monitored bat activity continuously at each site, with recordings being made for an average of 27 ( SD 8) nights per site.

### *Sound Analysis*

We processed bat calls with Kaleidoscope Pro (v.1.1.20, Wildlife Acoustics, Massachusetts, USA) with British bat classifiers (v.1.0.5). Noise files were removed and all bat sonograms were manually verified to species level (with the exception of *Myotis* spp. and *Plecotus* spp. which were identified to genus level and were grouped together within genera-wide

categories). A bat pass was defined as a continuous sequence of passes separated by a minimum of one second from other passes.

### *Data analysis*

Data analysis was undertaken using R version 2.14 [S6] and plots were produced using the ggplot2 package [S7].

We performed Mann-Whitney U tests to determine if there was a difference in either post-construction bat activity or fatalities based on whether pre-construction surveys identified the presence or absence of bats.

Spearman's Rank correlation coefficient was used to assess the relationship between the rank of perceived risk to bats (based on EcIA – see section 3.2) and the rank of the casualty rate. The same approach was used to assess the link with the rank of bat activity.

### *Results*

Eighteen EIAs concluded that an assessment of bat presence/activity was not required at the proposed wind farm site, or that there would be no significant effects on any protected species. However, half of these sites subsequently were found to have bat casualties (ranging from one to 64 per month) and 89% of these sites had evidence of bat activity post-construction (ranging from one to 236 passes per night).

The binary classification of sites according to whether bats were present or absent at the pre-construction survey was not linked with casualty risk (Mann-Whitney *U* test:  $U = 66.5$ ,  $N_1 = 11$ ,  $N_2 = 18$ ,  $P = 0.14$ ; Figure 1). Similarly, the reported presence or absence of bats pre-construction was not related to post-construction bat activity (Mann-Whitney *U* test:  $U = 95$ ,  $N_1 = 11$ ,  $N_2 = 18$ ,  $P = 0.87$ ; Figure S1a).

There was a significant, but marginal, positive relationship ( $\rho(29) = 0.36$ ,  $p = 0.05$ ) between the rank of perceived risk to bat populations casualty risk (Figure 3). Sites perceived to be of high risk to bats pre-construction had the highest casualty rates, whereas those with little bat activity (Table S1) had relatively low levels of bat fatalities. There was no significant relationship ( $\rho(29) = 0.11$ ,  $p = 0.57$ ) between sites ranked by perceived risk to bat populations and sites ranked by bat activity (Figure S1b).

### *Supplemental References*

S1. Mathews, F., Swindells, M., Goodhead, R., August, T. A., Hardman, P., Linton, D. M., and Hosken, D.J. (2013). Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: A blinded randomized trial. *Wildl. Soc. Bull.* 37, 34–40.

S2. Hamilton, P. B., TM Uren Webster, M. Basiewicz, E. V. Kennedy, E. S. R. De-Bastos., and Mathews, F. (2015). A rapid PCR-based test for identification of fifteen British bat species. *Conserv. Genet. Resour.* 7, 651-657.

S3. Huso, M.M. and Dalthorp, D. (2014). Accounting for unsearched areas in estimating wind turbine-caused fatality. *J. Wildl. Manage.* 78, 347-358.

S4. Brinkmann, R. (2005). Survey of possible operational impacts on bats by wind facilities in Southern Germany. Final report submitted by the Administrative District of Freiburg, Department of Conservation and Landscape Management and supported by the foundation Naturschutzfonds Baden-Württemberg. Brinkmann Ecological Consultancy. Gundelfingen/Freiburg, Germany.

S5. Brinkmann, R., H. Schauer-Weisshahn, and F. Bontadina. (2006). Survey of possible operational impacts on bats by wind facilities in Southern Germany. Final report submitted by the Administrative District of Freiburg, Department of Conservation and Landscape Management and supported by Naturschutzfonds Baden-Württemberg. Brinkmann Ecological Consultancy, Gundelfingen/Freiburg 229.

S6. R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

S7. Wickham, H. (2009) ggplot2: Elegant Graphics for Data Analysis, Springer-Verlag New York, 2009.