**Bird and bat species’ global vulnerability to collision mortality at wind farms revealed through a trait-based assessment Appendix 3. doi.org/10.1098/rspb.2017.0829**

Rationale for species’ traits selection for species included in the meta analysis.

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For birds,hypotheses governing potential sensitivity of species were considered based on species traits selected a priori potential pathways of impacts; predictions were made for each hypothesis and where opposing predictions were equally plausible, non-significant effects were potentially anticipated (Table S1). The following hypotheses were examined:

*(1) Habitat type*–Wind farms could impact species associated with habitats in which wind farms are typically situated. Although all habitats may contain wind farms, it was anticipated that species associated with open open habitats (e.g. farmland, grassland) would offer the greatest potential for collision.

*(2) Foraging strata*– The local niche and height that a species may utilise [1] may influence flight behaviour and therefore collision rates. In the absence of widespread information about speices’ flight height, we used foraging strata as an alternative.

*(3) Diet*– Depending upon the effect of wind turbines upon food availability, species’ diet may have either positive or negative impacts on collision rates. However, we predicted that scavenging and invertebrate consumers were likely to be at higher risk of collision as the availability of such prey may be greater close to turbines [2]. Habitat, foraging strata and diet were specified using binary factors in the analysis for each factor-level, allowing species to occupy multiple levels (e.g. being associated with more than one habitat-type).

*(4) Migration and (5) dispersal distance*– Flight activity, described by variation in both migration strategy and dispersal distance, is likely to be a key determinant of collision rate. We predicted that migrant species and long-distance dispersers may be at higher rate of collision, although not-necessarily in a linear fashion as species travelling longer distances may show differing behaviour such as higher flight altitude, thus in turn reducing their risk. (6) *Population size*– There is likely to be at least a weak relationship between species’ abundance and collision rate [3]. Although we lacked information about local abundances at individual sites, as a surrogate we used an estimate of global population size, which will be related to likely density of a species if present.

*(7) Flight manoeuvrability and (8) body size*– The ability of birds to avoid collision may depend on their flight ability. This is difficult to measure directly, but it can be inferred from Kipp’s Distance (KD), a measure of wing pointedness. We estimated KD as the length from the tip of the first secondary to the tip of the longest primary, measured on the folded wing [4]. Species with longer, more pointed wings are generally stronger fliers with higher levels of dispersal [5]. In addition, they probably spend more time airborne, and may be less manoeuvrable, particularly when their body size is large. For these reasons, we predict that species with high KD will collide more frequently with turbines. However, we note that exceptions to this general pattern will occur, for instance species such as swallows and hummingbirds will have a high KD and high manoeuvrability. Flightless species were not considered the study due to lack of perceived collision impact. We also used body size as an indirect measure of maneuverability, with larger individuals less maneuverable and therefore more likely to collide with wind turbines.

*Life history characteristics of* (10) *clutch size* *and (11)* G*eneration length*. These traits relate to potential correlations between species’ life-history and flight activity, for example due to impacts on parental effort and flight behaviour during the breeding season, generation length and the length of the juvenile period when birds may be more or less susceptible to collision. Traits for birds were not highly correlated (Pearson r < 0.7).

For bats, consideration of species traits for bats were restricted by the amount of data that was available within the PanTHERIA database [7]. Most variables that may govern susceptibility of birds to collision also apply for bats (Table S1), but due to a lack of equivalent trait data it was not possible to test habitat type, diet or foraging strata (see methods). The following variables were therefore considered (numbers of species in the PanTHERIA database are provided): (1) Population group size, defined as the number of non-captive animals in a group that spent most of their time in a 24-hour cycle together [7], 131 species; (2) forearm length, 967 species; (3) body mass, 759 species; (4) Litter size, 426 species; (5) age of sexual maturity, 131 species and (6) gestation length, 190 species. We used population group size as an appropriate measure for population size, forearm length as a measure of manoeuvrability, and litter size, age of sexual maturity and gestation length as measures relating to life-history characteristics. Age at sexual maturity and gestation length were not significantly correlated (R = 0.23, P > 0.05), but body mass and forearm length were (R = 0.92; P < 0.001), so forearm length was excluded – see electronic supplementary material appendix A4 for more information on correlation tests for fixed effects of species traits. Additional variables of (7) dispersal distance, (8) use of tree roost sites and (9) hibernation behaviour were also extracted for bat species from the IUCN Red List [8], Animal Diversity Web [9], and other databases such as the United Nations Environment Programme (UNEP) ‘EUROBATS’ project initiative [10]. These data sources themselves were reviews of information on the desired traits. A simple definition was provided in [10] for categorising dispersal distance as a three-tier category of sedentary (<10 km), regional (10-100 km) and long-distance migrants (100+ km), which also tallied with other databases including North American species [9]. Roosting habitiats also followed definitions in [8-10]; however to test the prediction that tree-roosting species may be more vulnerable than species roosting in other habitats [11] – see also electronic supplementary material Table S1 – we simplified roosting definitions to those species associated with roosting in ‘trees’ or not; note this also amalgamated different types of roost sites for daytime, nightime, transitory and maternity roosts [10], which was necessary to avoid over-fitting our model based on a limited number of species. Information on whether a species experienced extended hibernation overwinter was also extracted [8-10].

**Table S1.** Traits of birds and bats, characteristics of wind farms and confounding variables believed to potentially influence vulnerability of species to collision with wind turbines.

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| **Trait** | **Taxa applicable to** | **Predictions and rationale for how trait could influence vulnerability to collision** | **Levels / trend assessed** |
| Habitat association | Bird | Habitat association of species will influence vulnerability if species occur where wind farms are situated – species associated with human-impacted artificial habitats and open grassland are predicted to have greater impact than other species. | Artificial, forest, grassland, desert, coastal, marine |
| Tree roosting sites | Bat | Tree roosting species will be at greater risk of collision, due to species identifying wind turbines as trees, and attraction to insect prey [11]. | Tree vs non-tree roosting |
| Foraging strata | Bird | Species foraging in particular strata are more likely to interact with turbines; aerial and tree foragers are more often at turbine height rendering them more vulnerable; ground and water foragers are below turbine height and will be less impacted. | Water, ground, tree, aerial |
| Diet | Bird | Diet may bring species more into contact with wind farms if their preferred food overlaps with wind farms – scavenger and vertebrate consumers may be more impacted through attraction to areas of high densities of small mammalian prey [6], invertebrate feeders may be more vulnerable if prey is attracted to wind farm; fruit/nectar feeders less impacted due to unlikely abundance of food sources in wind farm locations. | Invertebrate, vertebrate, scavenger, fruit/nectar, plant/seed |
| Migration status | Bird | Migratory species travel greater distances and are therefore more likely to interact with wind farms than non-migrants; conversely, non-migrants may remain in an area longer and could therefore be more exposed to wind farms thanmigrants. | Migrants/non-migrants |
| Dispersal distance | Bird & Bat | Species with larger dispersal distance are more likely to come in contact with wind farms; species with largest dispersal may travel above the height of turbines, reducing collision rates. | Trend over dispersal categories 0-100+ km |
| Hibernation | Bat | Bat species that hibernate are dormant for a period of the year, thus reducing their overall exposure and eventual vulnerability to wind farms. | Hiberanting vs not hibernating |
| Kipp's distance | Bird | Species with high Kipp's distance (i.e. thinner, more pointed, wings) have stronger flight ability and therefore increased likelihood of encountering wind farms. In addition, they may have reduced manoeuvrability and less ability to avoid collisions through last-minute adjustments to flight path. | Trend |
| Body mass | Bird & Bat | Larger species are more likely to collide due to reduced manoeuvrability. | Trend |
| Global population | Bird | Species with larger populations collide more frequently than scarcer ones. | Trend |
| Population group size | Bat | Species that live in larger social groups more likely to collide with turbines. | Trend |
| Life history traits | Bird and Bat | Bird and bat species may be k- or r-selected, balancing individual fitness vs current and future reproduction. Collision rates may be higher for breeding individuals than non-breeders as foraging activity is higher for breeders to meet energetic demands of both offspring and parent (\*central to traits below). | General information\* |
| Generation length | Bird | *k*-selected species with longer generation length place greater emphasis on adult condition rather than offspring thus reducing foraging time amounts and risk of collision. Conversely however, k-selected species have more reproductive events per life span resulting in potentially equivalent exposure per reproductive lifespan than species with shorter generation lengths\*. | Trend |
| Clutch size | Bird | *r*-selected bird species with larger clutch size (and brood size) investing more in current reproduction may have greater per capita exposure per unit time to collision than species with smaller clutch sizes\*. | Trend |
| Gestation length | Bat | *k*-selected species with a longer gestation length may be actively gathering more resources over a longer time period than species with reduced gestation lengths, and therefore may be at higher risk of collision\*. | Trend |
| Age at sexual maturity | Bat | *k*-selected species maturing at an older age have longer before breeding constraints occur thus reducing collision\*. | Trend |
| Number of litters per year | Bat | *r*-selected species that are more productive within a given breeding year will forage for their young for longer than those less productive species, and may therefore be at higher risk of collision\*. | Trend |
| Number of wind farms | Bird & Bat | More individual wind farms may influence the overall collision metric for species by providing more information per study, and thus was accounted for. | Trend |
| Turbine size | Bird & Bat | Larger wind turbines may cause increased collision rate due to greater hub height and collision sweep area. | Trend |
| Buffer Area | Bird & Bat | Larger surveyed areas could find more victims, although most studies tailored their survey plot areas to try and encompass all likely victims. | Trend |
| Peer review | Bird & Bat | Peer-reviewed studies subject to strict scrutiny, are more likely correct for carcass detection resulting in higher collision rates (see quality below); however, a high proportion of grey literature also included such corrections. | Peer/non-peer |
| Quality | Bird & Bat | Higher quality studies correct for most sources of bias, higher estimates of collision rates predicted. | Very low, low, medium, high |
| No. years | Bird & Bat | Greater duration of study could influence collision estimates of species, and was therefore accounted for. | Trend |
| Days/year | Bird & Bat | Longer within-year monitoring might lead to higher estimated collision rates, but only if many collision victims were missed outside the monitoring period, which is unlikely since efforts were made to target key periods/life history phases. | Trend |

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