Linking bat surveys with meteorological data: a way to target operational wind farm mitigation

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Ecologists and energy developers are aware that wind turbine operation can result in bat mortality through direct collision and barotrauma. This article considers the use of operational cut-ins to control turbine activity at times when bats are active in order to reduce the likelihood of potential bat mortality. We also highlight the need to consider survey height, wind conditions and temperature within the rotor-swept zone when designing mitigation measures.

Temporal and seasonal variations are regularly used to predict bat activity, hence the guidance available on the suitability of survey timings (Hundt 2012). Studies have identified a link between bat activity and wind speed and some have focused on the amount of bat activity recorded at height in comparison to that recorded at ground level (Collins and Jones 2009, Gray *et al*. 2012, Cryan *et al*. 2014). Building on this work, this study collected bat activity data and the corresponding wind speed and temperature data at both ground level and within the rotor-swept zone at four proposed wind turbine sites across the UK. The results highlight the importance of the elevation at which wind speed and temperature are measured when designing and implementing mitigation triggers. Targeted mitigation during specific wind speeds and at certain temperatures has the potential to increase the economic viability of problem turbines while minimising potential bat mortality.

Introduction

The potential for wind turbines to cause bat mortality has been established by a range of studies (Baerwald *et al*. 2008, Cryan *et al*. 2009, Ellison 2012). At present, when trying to reduce this mortality, the only effective avoidance measures available are appropriate siting and reductions in the size or number of turbines to be installed (Barclay *et al*. 2007, Mitchell-Jones and Carlin 2012). Inevitably, the cost implications of reducing the number or size of turbines, and the vast number of other constraints on each site, create pressures to install turbines in sub-optimal locations from an ecological point of view. In these cases, there is a need to manage the risk to a range of wildlife. Reducing the risk during the construction phase is usually relatively straightforward because of the small development footprint, short duration of works and wide range of reliable mitigation measures available. In contrast, the risk to wildlife during operation is on-going with few easily implemented mitigation measures available.

Another option is the implementation of operational activity cut-ins, a method whereby a wind turbine is stopped, slowed or started during specific climatic conditions during times when bats are active (Baerwald *et al*. 2009). Recent research has shown that ultrasonic acoustic deterrents or even the addition of aviation lighting can also reduce mortality at test sites in the USA (Arnett *et al*. 2013, Bennett and Hale 2014). However, further research and testing of these novel methods is required to assess their effectiveness in the UK.

Triggers for the implementation of mitigation measures once turbines are operational are usually specific wind speeds but ambient temperature, wind direction or precipitation could also be used. The implementation of operational cut-ins for bats is usually designed to target the times when bats are most likely to be active, i.e. just before sunset and just after sunrise. By correlating meteorological conditions with peaks in bat activity during these times, we can identify the periods during which the curtailing of wind turbine operation would be most effective at reducing potential bat mortality while maximising the energy and revenue generated by the wind farm.

Soprano pipistrelle. Photo by Robert Bell

This study examined whether wind speed and temperature limit bat activity and whether this is consistent at height and at ground level. This article also considers whether it is possible to design regional or national guidance on thresholds for cut-ins to address the risks caused by high levels of bat activity around a proposed turbine, and whether this guidance needs to be species-specific.

Data Collection

The combined dataset was taken from sites located in South West England, Central England, and two sites in the Scottish Borders. The habitats present within the sites comprised arable farmland, grazed pasture, and clear-fell within actively managed, coniferous plantation woodland.

Metereological masts (70 m tall) were erected on each site, and rigged with thermometers, anemometers, and an SM2 bat detector with two SMX-US microphones (Wildlife Acoustics, MA, USA), set to record simultaneously. One of the SM2 microphones was mounted at ground level (3 m), with the second mounted at a height that would be within the rotor-swept zone of a turbine (50 m). Data from the recording instruments closest to each SM2 microphone were matched with the bat activity recorded at that height. The thermometers were positioned at elevations of 3 m and 65 – 66 m and anemometers at 25 – 25.5 m and 55 m.

Data were collected over a period of 74 nights with recordings commencing half an hour before sunset and finishing half an hour after sunrise, times when bats could reasonably be assumed to be active. The average temperature and wind speed were logged for each ten-minute recording period then rounded to one decimal place. Any recorded bat activity was matched to the relevant ten-minute recording period, giving a total of 3,538 ten-minute recording periods with wind speed, temperature and species-specific bat presence / absence data. The subsequent analysis included all meteorological data logged during the ten-minute periods when the SM2 was active, irrespective of bats being detected. This allowed analysis of the meteorological conditions when bats were not recorded but had the potential to be active, based on the typical bat activity periods given in the Bat Conservation Trust survey guidelines (Hundt 2012). Therefore any correlation between a lack of bat activity, or a reduction in bat activity, and corresponding weather conditions could be identified.

Limitations

As with most studies of this kind, some limitations should be considered when reviewing the results. Firstly, the dataset is not a comprehensive record of bat activity at each site (i.e. bats were not surveyed on every night of their active season). However, we believe the dataset provides sufficient information from which to draw conclusions for the combined sites.

Bats with quieter calls, for example *Plecotus* species, will not be picked up from as great a distance as bats with loud calls, and may even be completely drowned out by background noise, such as wind. When prospective wind turbine sites are being surveyed, it is likely that wind noise will reach levels that reduce the detection rate of quiet species should they be present during high wind speeds. Conversely, it is possible that bats with loud calls, such as *Nyctalus* species, may be recorded by both microphones at once. Unfortunately, these practical limitations cannot be corrected for when designing the survey or collecting the data and therefore need to be taken into account when analysing the data and designing appropriate mitigation.

Finally, the data used in this study were limited by the geographical location of the meteorological masts. The distribution of different species varies across the country, thus the data were skewed towards certain species simply due to their relative abundance at the sampling location.

Analysis

The data were grouped by sampling height into 3-m and 50-m categories for each bat species or group, and combined for all bat activity recorded. The cumulative percentage of bat activity at each 0.1-m/s interval of wind speed and 0.1°C interval of temperature was calculated and represented graphically, together with the frequency at which each 0.1°C temperature interval or 0.1-m/s wind speed interval was recorded.

Results

In total, five species / species groups were recorded during the study, namely *Plecotus, Myotis* and *Nyctalus* as well as common and soprano pipistrelle (*Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*, respectively). Although four of the species groups were recorded at both 3-m and 50-m elevations (the *Plecotus* species group was only recorded at 3 m), 84% of bat activity was recorded at the 3-m elevation, see Table 1.

Wind Speed

During the recording period, wind speed was significantly different at the two heights (ANOVA test comparing wind speed at elevations of 25-25.5 m and 55 m), see Figure 1. At an elevation of 50 m, 80% of all bat activity was recorded at wind speeds of 5.4 m/s or below. These wind speeds were logged for 34.6% of the total recording time. All bat activity was recorded at wind speeds of 11.8 m/s or below, corresponding to 99.9% of the recording period. At an elevation of 3 m, 80% of bat activity was recorded at wind speeds of 5.3 m/s or below, corresponding to 69.2% of the total recording time. All bat activity was recorded at wind speeds of 8.3 m/s or below, corresponding to 97.9% of the recording period.

To summarise, Figures 1 and 2 show that bats began flying when there was no wind (0 m/s) and could tolerate most wind speeds. However, the level of bat activity was greatly reduced at wind speeds of around 5.4 m/s and above.

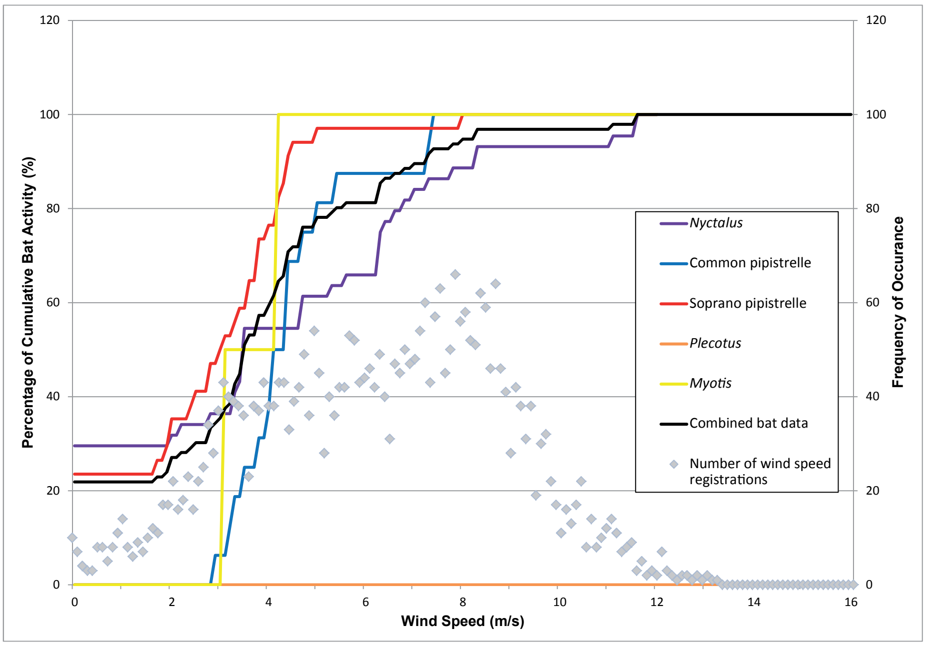

Figure 1. Cumulative number of bat registrations (recorded as a percentage of total bat activity) as wind speed increases at an elevation of 50 m

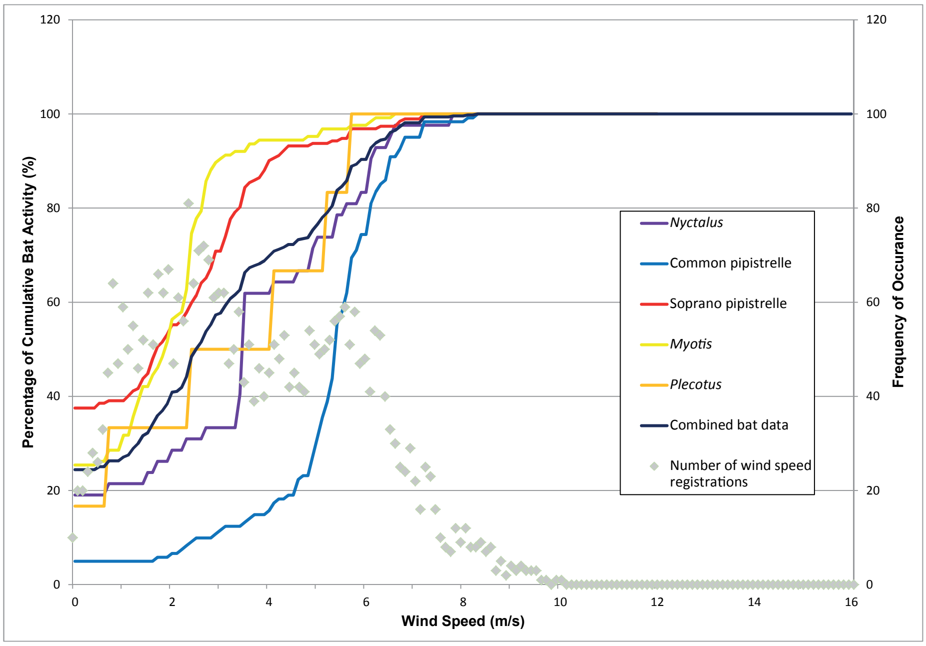

Figure 2. Cumulative number of bat registrations (recorded as a percentage of total bat activity) as wind speed increases at an elevation of 3 m

Table 1. Cumulative number of bat registrations recorded during 3,538 ten-minute recording periods

Species	Number of registrations	
	At 50 m	At 3 m
Plecotus species	0	6
Myotis species	2	126
Nyctalus species	44	43
Common pipistrelle	16	121
Soprano pipistrelle	34	198
Total activity	**96**	**494**

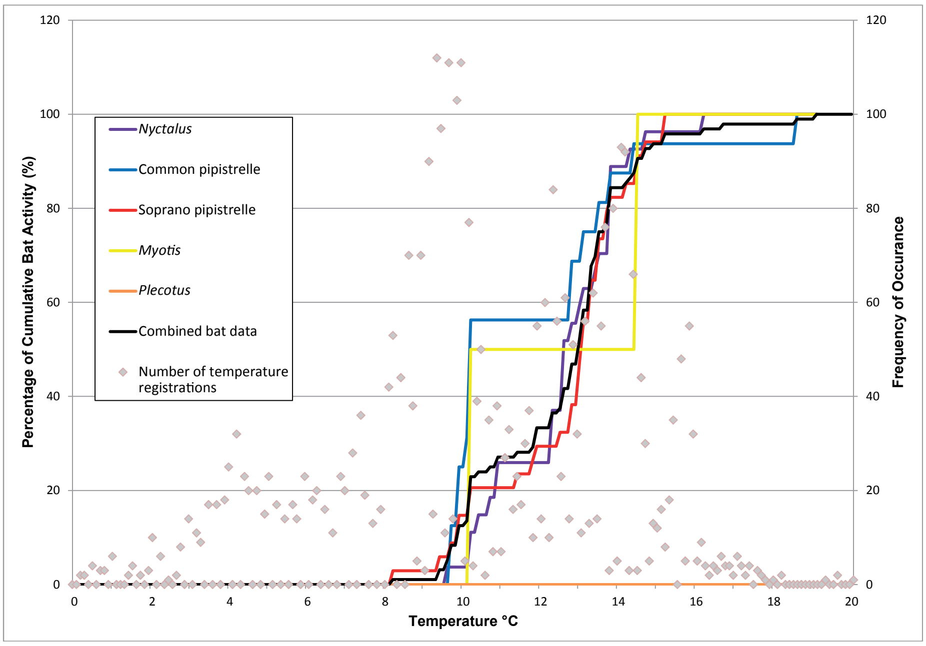

Figure 3. Cumulative number of bat registrations (recorded as a percentage of total bat activity) as temperature increases at an elevation of 50 m

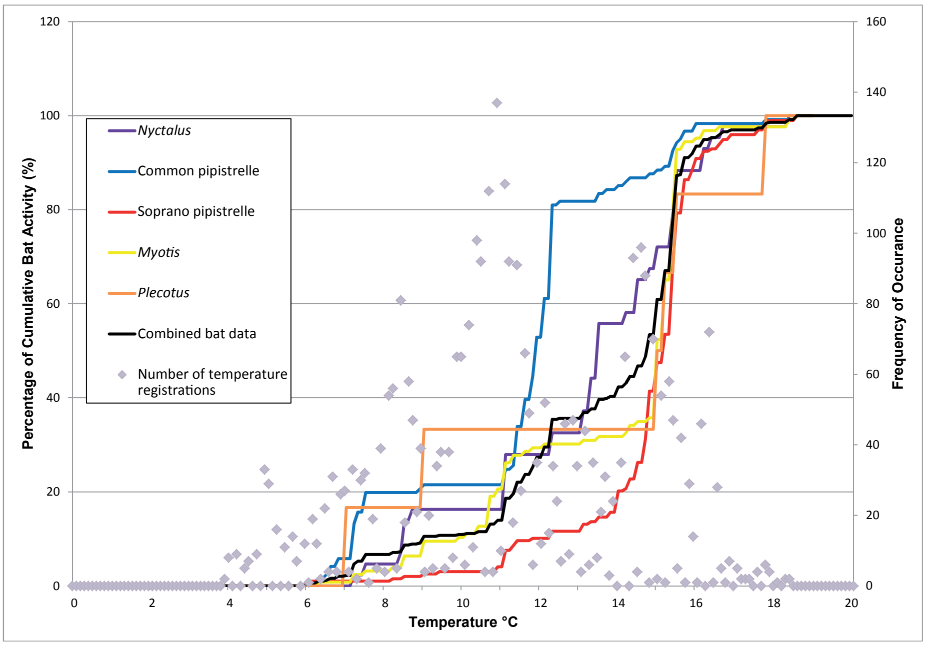

Figure 4. Cumulative number of bat registrations (recorded as a percentage of total bat activity) as temperature increases at an elevation of 3 m

Table 2. Climatic conditions during which 80% of bat activity was recorded

Species	Wind speed (m/s) below which 80% of activity was recorded		Temperature (°C) above which 80% of activity was recorded	
	At height	Ground level	At height	Ground level
Plecotus species	n/a	5.2	n/a	8.9
Myotis species	3.1	2.7	10.1	10.8
Nyctalus species	6.8	5.6	10.8	11.0
Common pipistrelle	5.0	6.1	9.8	8.8
Soprano pipistrelle	4.2	3.4	10.1	13.9
Total activity	**5.4**	**5.3**	**10.1**	**11.3**

Figures 1-4: Cumulative bat activity (expressed as a percentage) is denoted by the coloured lines. The frequency that each 0.1°C temperature or 0.1 m/s wind speed was logged as the average temperature or wind speed for a 10-minute recorded period is denoted by the grey diamonds.

Temperature

Temperature was significantly different at the two heights (ANOVA test comparing temperature at 3 m and 65-66 m). At an elevation of 50 m, only 20% of bat activity occurred at below 10.2°C; this corresponds to under half (45.1%) of the recording period. No bat activity was recorded at temperatures below 8.2°C, comprising just 17.2% of the recording period. At an elevation of 3 m, only 20% of bat activity occurred at temperatures below 11.4°C, corresponding to 53.5% of the recording period. No activity was recorded at temperatures below 6.1°C, although this comprised a very small proportion (4.2%) of the recording period.

To summarise, Figures 3 and 4 indicate that no bat activity occurred at temperatures below 6°C. Below approximately 10°C, bat activity was extremely limited even though this corresponded to about half of the recording time (i.e. approximately half of the time bats could otherwise reasonably be expected to be active).

Species

Certain species of bat are at higher risk from wind turbines due to their diet, roost preferences and flight patterns (Mitchell-Jones and Carlin 2012). These differences mean that the potential risks posed by a wind farm development may need to be considered on a species-specific basis. Table 2 shows the wind speed below which 80% of each species' activity was recorded, and temperature above which 80% of the bat activity for each species was recorded.

In this study, *Nyctalus* species and common pipistrelle were more tolerant of higher wind speeds than *Myotis* species and soprano pipistrelle. Most species were more active during higher wind speeds at ground level than at the 50 m elevation with the notable exception of *Nyctalus* species. Common pipistrelle and *Plecotus* species were more frequently active at lower temperatures than the other species recorded. See Table 2.

Feature Article: Linking bat surveys with meteorological data: a way to target operational wind farm mitigation (contd)

Conclusions

This study shows that records of species diversity and bat activity were significantly reduced at an elevation of 50 m when compared to those recorded at an elevation of 3 m. Therefore, while surveys undertaken at ground level may not accurately reflect the species composition and level of activity within the rotor-swept zone of a wind turbine, they are likely to provide a figure which can be used as a precautionary value.

When designing operational cut-ins for wind turbines, it is important to note that the temperature and wind-speed thresholds limiting bat activity 'at height' may not be the same as those 'at ground level'. When designing mitigation measures such as a reduction in turbine activity below a certain wind speed or above a certain temperature, it is therefore important to state the height at which the wind speed or temperature will trigger the operational cut-in.

It has long been known that temperature affects the level of bat activity. Bat Conservation Trust guidance recommends that bat transect surveys for wind farm developments are undertaken on evenings with dusk temperatures of 10°C or above (Hundt 2012). However, this is often overlooked when designing operational cut-ins. This study indicates that curtailment of a wind turbine when bats are likely to be active (i.e. from half an hour before sunset until half an hour after sunrise, March and October inclusive) when wind speeds fall below 5.4 m/s and when temperatures are above 10.1°C (recorded at an elevation of 50 m) will be likely to reduce the potential impact to bats (as a group) by 80% during these times. Clearly this is a simplified figure which assumes that bats would neither be attracted to nor avoid an operating wind turbine, and that the climatic variables would not affect the ability of a bat to avoid a collision or barotrauma.

Ultimately, it will not be appropriate to undertake analysis to the level of detail reported in this article for wind farm sites where the impact to bat populations is not expected to be significant. Where it is required, a threshold that balances the need to avoid turbine operation during periods of high bat activity, while keeping the turbine economically viable, would need to be set. Therefore, at present, this level of detailed analysis is likely to continue to be used primarily to combat species-specific problems at specific turbines and, in general, operational cut-ins are unsuited to a standard, blanket approach. However, as the amount of data and number of recording sites increase, it may be possible to identify species-specific or general guidance in the future. The effects of survey height on the records of species diversity and bat activity have immediate relevance. Linking these data to meteorological data to determine the wind speeds and temperature during which bats are likely to be active should allow effective and targeted mitigation to be designed and implemented.

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