BATS AND ONSHORE WIND TURBINES: SURVEY, ASSESSMENT AND MITIGATION

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This document has been prepared jointly by NatureScot (Scottish Natural Heritage), Natural England, Natural Resources Wales, RenewableUK, Scottish Power Renewables, Ecotricity Ltd, the University of Exeter and the Bat Conservation Trust (BCT) with input from other key stakeholders.

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1 PURPOSE

The purpose of this document is to help planners, developers and ecological consultants to consider the potential effects of onshore wind energy developments on bats. The emphasis is on direct impacts such as collision mortality, but there is reference throughout to the need for a full impact assessment requiring a wider consideration of other (indirect) effects[1]. It replaces the previous guidance on the subject; notably that published by Natural England (TIN051) and chapter 10 of the Bat Conservation Trust publication *Bat Surveys: Good Practice Guidelines* (2nd edition), (Hundt, 2012) and tailors the generic Eurobats guidance on assessing the impact of wind turbines on European bats (Rodrigues *et al*. (2014)) to the UK. It is not intended for use in relation to single wind turbines, micro installations (under 50kW) or offshore wind farms, although some aspects of the guidance may be relevant. It guides the user through the key elements of survey, impact assessment and mitigation.

The guidance draws on the findings of the Defra-led research Understanding the Risk to European Protected Species (bats) at Onshore Wind Turbine Sites to inform Risk Management (Mathews *et al*. (2016)) hereafter referred to as the National Bats & Wind Turbines Project and on the growing body of evidence from European and North American research (see Eurobats Advisory Committee *Intersessional Working Group (IWG) on Wind Turbines and Bat Populations* reports for annually updated reviews of the evidence base, e.g. UNEP/EUROBATS IWG (2019)). The guidance will be further refined and updated in the light of new evidence and user feedback.

2 LEGAL CONTEXT

Bats and their roosts are legally protected by domestic and international legislation. The purpose of the legislation is to maintain and restore protected species to a situation where their populations are in a favourable conservation status. Although the wording of the relevant legislation differs slightly between the UK countries, the act of killing a bat is an offence if undertaken with a degree of intention or recklessness (unless permitted under licence).

Bat casualties at wind farms are likely to be considered an example of incidental killing as described in guidance to the Habitats Directive[2] and may not therefore be an offence, but at a certain level of impact such killing may cease to be incidental and become intentional or reckless (according to domestic law). The level of impact that will trigger this change is a matter for courts to decide, though the implementation of appropriate mitigation measures is likely to lessen the risk of mortality and therefore the possibility of an offence being committed.

3 ASSESSING POTENTIAL IMPACTS

Wind farms can affect bats in the following ways:

1. Collision mortality, barotrauma and other injuries (although it is important to consider these in the context of other forms of anthropogenic mortality)
2. Loss or damage to commuting and foraging habitat, (wind farms may form barriers to commuting or seasonal movements, and can result in severance of foraging habitat);
3. Loss of, or damage to, roosts;
4. Displacement of individuals or populations (due to wind farm construction or because bats avoid the wind farm area).

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[1] These include loss roosts, of commuting and foraging habitat and habitat fragmentation and should be considered and addressed as indicated in Chapters 4-9 in *Bat Surveys for Professional Ecologists: Good Practice Guidelines* 3rd edition (Collins, 2016). Other chapters in this publication are also relevant. See also CIEEM (2018) *Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal.*

[2] See page 49, paragraph 83 in Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC (2007)

To ensure that bats are protected by minimising the risk of collision, an assessment of impact at a site requires a detailed appraisal of:

- The level of activity of all bat species recorded at the site assessed both spatially and temporally.
- The risk of turbine-related mortality for all bat species recorded at the site during bat activity surveys.
- The effect on the species' population status if predicted impacts are not mitigated.

The above information should be interpreted in the context of likely impacts on local populations. Relevant factors that should be considered include whether populations are at the edge of their range, cumulative effects, presence of protected areas designated for their bat interest and proximity to maternity roosts, key foraging areas or key flight routes, including possible migration routes.

3.1 *Life Extension and Re-powering*

In addition to new projects, many future onshore wind energy proposals will involve life extension (i.e. continued operation beyond the original planning consent period) or re-powering of existing sites (i.e. replacement of turbines with new, and often larger, turbines). It cannot be assumed that changes to existing sites present lower risks to bats than the construction of new turbines at previously undeveloped locations, so proposals to amend existing sites should be assessed before permission is given by the relevant body.

If bat surveys have been undertaken at sites that may still be relevant (e.g. there have been no significant habitat changes since the original surveys were undertaken and the surveys are no more than two years old), the results should be used to assess whether the proposed changes are likely to increase the risk of bat mortality, and what, if any, mitigation should be applied. Casualty searches and/or acoustic monitoring at height around existing turbines will add to the evidence base and the former, in particular, are strongly recommended at such sites. If no surveys or monitoring have been undertaken, the methods proposed here for new developments should be used as the basis for assessing the risk.

4 APPROACH

4.1 *Desk Study*

Information should be gathered to help plan survey work and provide context for an assessment. The desk study should review all the available information on bats relevant to a proposed wind farm site and consider the various factors that influence risk to the species at a site. This should include:

- Recent aerial photographs (and other photographs), maps and habitat survey maps of the proposed site to identify features of potential value to bats. Assessors should be mindful that habitats, notably commercial forests, may change during the scoping period for projects and also during the construction phase, and therefore evidence should be provided (e.g. by ground truthing) that remotely sensed data will be relevant once the wind turbines are operational.

- The collation of relevant bat information within 10 km of the proposed wind energy site, including species and roost records and the proximity of national and internationally designated sites for bats. In areas with low levels of biological recording (such as uplands), particular effort should be made to identify locations with potential to house significant roosts, such as barns and other buildings.

- The location of the site in relation to the edge of the species' known GB range. Information on species distribution is available in the 2019 UK Habitats Directive Article 17 Report. The potential for negative impact is likely to increase where there are high risk species on the edge of their range.

- The location of other wind energy developments, including the number of turbines and their size, within the surrounding 10km in order to inform an assessment of cumulative pressure. Local Planning Authority websites should also be checked for the presence of single wind turbines within 10km of the proposed wind farm as the presence of nearby single turbines, while not the focus of this guidance, may still contribute to cumulative effects. Additionally, other infrastructure (e.g. major roads) and other developments that may have an effect on local bat populations within the area need to be considered. Further consideration over a larger area than the above 10km radius may be required in certain circumstances, for example at locations judged likely to be on flight-paths used for swarming, where the arrival of hundreds of bats within a single night can occur.

Collins (2016) Bat Surveys for Professional Ecologists: Good Practice Guidelines (3rd edition) (currently under revision) provides further detail on undertaking desk studies.

4.2 ***Bat surveys***

The main information required from surveys is:

- The species assemblage. Bats should be identified to species, or where these cannot be separated with confidence, to species group e.g. *Myotis* sp. or Nyctaloid bats (see Collins [2016] section 10.2.3) using the site.

- The locations of roosts (particularly maternity and hibernation) and swarming sites in the surrounding area that could be affected by the wind farm proposals at the site.

- The location and extent of commuting or foraging habitat used by bats. This needs to include not only the site itself, but also flight paths and habitats in the surrounding landscape that are likely to bring bats to the site. The information may also be useful where habitat management is considered as a mitigation measure for predicted impacts on other species (e.g. raptors).

- The amount of bat activity on the site, and its spatial and temporal distribution.

Project-planning needs to allow sufficient time to undertake the bat surveys at the appropriate spatial and temporal scale.

Bat activity varies considerably both between and within years and on a nightly basis. It is evident that multiple nights of surveying are required to determine accurately species presence and distribution within a site and to correctly categorise the relative level of activity of each species.

Pre-application surveys should take place over a full season of bat activity. Additional survey may be required:

- when prolonged unusual or inclement weather is considered likely to have significantly influenced bat activity during the surveys undertaken;
- where land management changes have taken place since the survey and these are considered likely to significantly influence bat activity;

- at large sites where there is increased potential for high variability in the pattern of bat activity and it is not practical to undertake the minimum level of recommended survey (below) in one active season;

- at sites considered likely *a priori* to be important to local populations, e.g. close[3] to areas designated as SSSI and/or SAC for their bat interest.

5 METHODS

Acoustic surveys using bat detectors should be undertaken to identify the species assemblage and the spatial and temporal distribution of activity. The range of methods used and survey effort involved will, to some extent, be informed by information gleaned from the desk study and will be site- and species-dependent.

5.1 *Roost surveys*

Key features that could support maternity roosts and significant hibernation and/or swarming sites (both of which may attract bats from numerous colonies from a large catchment) within 200m plus rotor radius of the boundary of the proposed development should be subject to further investigation. The search area may need to be extended if there is a high level of habitat connectivity in the surrounding area and this is considered likely to attract bats into the wind farm area from further afield. The survey should establish presence or absence of roosts and if bats are present the species, numbers (or estimated numbers), function of the roost and flight lines away from the roost. See Collins (2016) for more details.

5.2 *Bat activity surveys*

Surveys should capture a sufficient number of nights with appropriate weather conditions for bat activity (i.e. temperatures of 10ºC and above (8ºC in Scotland) at dusk, maximum ground level wind speed of 5m/s[4] and no, or only very light, rainfall to fulfil the minimum requirements in Section 5.2.1. In practice, particularly in more northerly latitudes, there will be limitations on the number of suitable nights and some surveys may need to take place over longer periods which sample a range of conditions. This can provide an insight into how bats respond to poorer conditions and the data used in the choice of subsequent mitigation. In such cases, the survey period should be planned and justified by the ecologist and the effect on bat behaviour considered taking account of weather forecasts. In view of these practical constraints, detectors may need to be operational for considerably longer than the minimum period specified below. Full spectrum automatic detectors should be deployed wherever possible, as a minimum. Zero–crossing detectors may be used only where insufficient full spectrum detectors are available, *but should not be regarded by surveyors as a long-term solution* and full spectrum detector usage should be implemented at the earliest opportunity. Where full spectrum detectors are used, sound analysis must be carried out of the original full spectrum files, and not of converted zero-crossing versions.
Automated detector surveys should commence half an hour before sunset and finish half an hour after sunrise to ensure that bat species that emerge early in the evening and return to roosts late, such as noctules, are recorded.

Automated detectors are normally left in position to collect data all night. If they may be subject to interference due to public access to the site, security measures should be employed, such

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[3] Where the location of the nearest proposed turbine is within the core sustenance zone of any of the species for which the site is notified, see Collins (2016).

[4] See Ahlen *et al.* (2007) and Arnett *et al.* (2011)

as placing detectors in locked boxes. Timers determining the start and end times of the survey should be regularly adjusted through the season to take account of the variation in night length, (some detectors do this automatically).

5.2.1 *Ground-level static surveys*

The minimum level of pre-application survey required using static detectors is 10 nights in each of: spring (April-May), summer (June-mid-August) and autumn (mid-August-October[5]). Surveys in adjacent seasons should not be contiguous, i.e. they should be spaced out to include a reasonable time gap between them and should aim to include periods when migration could be taking place. Ideally, surveys should aim for 10 *consecutive* nights, but in practice weather conditions may preclude this particularly early or late in the year and in more northerly latitudes. The objective is to complete these surveys within a single calendar year, but in a few situations it is accepted that this may not be possible. In such cases, surveys can be split over two successive calendar years, but a justification must be provided to explain the reason(s) for this.

Survey effort should be focused in those parts of the development site where turbines are most likely to be located, although proposed turbine locations are often subject to change. At sites where the proposed turbine locations are known, static detectors should be placed to provide a representative sample of bat activity at or close to these points. Detectors should be placed at all known turbine locations at wind farms containing less than ten proposed turbines. Where developments have more than ten turbines, detectors should be placed within the developable area at ten potential turbine locations plus a third of additional potential turbine sites up to a maximum of 40 detectors for the largest developments. Thus, a development with 22 proposed turbines would require 14 static detectors. The selection of locations at which to place detectors should be based on professional judgement, but at large sites, it is recommended that beyond the initial ten detectors placed at proposed turbine sites (if known), the remainder should be distributed according to a system of stratified sampling based on the availability of different habitats and topographical features on the site.

At key-holed woodland/plantation sites (and other proposals involving extensive habitat alteration), pre-application survey data may not represent the situation post-construction, as the habitat available for bats will change following construction. Automated survey locations should therefore also include open areas including existing nearby rides/clearings in the forestry, to provide an indication of how bats may adapt to and use the new habitat created through turbine construction.

5.2.2 *Automated static surveys at height*

Monitoring at height can provide useful additional information on bat activity, but it is unlikely to detect the presence of any species not already recorded using detectors at ground level (except in woodland – see below). It is particularly relevant at proposed key-holed sites because of the difficulty of inferring above-canopy level activity from ground-based detectors (a proportion of the activity of high flying species (e.g. Nyctaloid species) is likely to be beyond the detection range of ground based equipment). Monitoring at height should only be considered where any of the following circumstances apply:

- other supporting evidence (e.g. from previous surveys of the site or other local sources) suggests a high level of bat activity within the height of the rotor-swept area,

[5] Ideally mid-August to mid-September. There is evidence from southern Scotland that this 4 week period often corresponds with a substantial seasonal peak in bat activity.

- existing infrastructure allows and is representative of the proposed changes (e.g. where a site extension is proposed and automated detectors may be fixed to the nacelles of existing turbines if they are of similar size to the new turbines),

- a meteorological mast is present or will be erected.

5.2.3 *Walked transect and vantage point surveys*

Either/both of these survey methods can be used to complement the information gained from static detectors and other sources, but their applicability is discretionary and site-specific. Static detectors provide an overview of how bat activity is broadly distributed over the site and which species are present, but are less suited to identifying flight lines and understanding the numbers of bats present. Information on these can be collected at certain times i.e. dusk and dawn, using these observational methods. The choice of method used at sites must be appropriate to identify connections between nearby roosts, linear features (or other potential flight paths, e.g. as used by Nyctaloid species) and potential key foraging areas across the development footprint[6]. The existence of such routes might be inferred from other available information, such as the presence of a linear feature within the development footprint linked to a known roost site nearby, and such field knowledge should be incorporated into the survey design. Vantage point surveys enable the surveyor to see a long way and across the landscape at early dusk when bats are still visible. They are particularly useful for observing early commuting and foraging species such as noctule bats whilst it is still light.

5.2.4 *Additional survey methods*

In some cases, the data collected in the pre-construction survey may indicate the need for further, more specialised survey techniques. For example, if there is a roost of high importance of a medium or high-risk species that may be vulnerable to impacts of the proposed development, further surveys of the roosts and/or radio-tracking may be appropriate to provide comprehensive information on the bats' use of the site. Some examples of other survey methods that could be considered are provided below. See also Collins (2016) for further details.

- *Back tracking surveys:* in some instances a back tracking survey to find a roost may be required as a follow-up to other methods to determine location of roosts;

- *Infrared cameras and low light video:* these can be used to help identify potential roost sites to determine the need to follow up surveys, but note that infrared may not always give the range and field of view needed to provide robust information in open habitats.

- *Thermal imaging cameras:* these detect heat emitted from bats and can be used to monitor flight lines and foraging behaviour over greater distances than infrared cameras. Depending on specific requirements different lenses can also provide different fields of view and magnification.

5.2.5 *Deployment and testing of automated static bat detectors*

Wind energy sites often have extreme weather conditions that can affect microphone integrity. Prior to deployment all static bat detectors, cables and microphones should be checked, and the microphones tested and adapted to operate at the same level of sensitivity. Equipment should be checked at regular intervals to ensure they have been operational and sufficient data are collected.

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[6] There may be other situations where these methods would be appropriate, for example where a watercourse passes through, or very close to the development footprint, in otherwise open and exposed moorland. Bats may use these features for foraging and as key commuting routes on warm, calm nights in the summer. These situations require site-specific judgement.

5.2.6 *Weather data*

Weather data including wind speed, temperature and rainfall are important for the interpretation of bat activity data, and should be recorded nightly for all types of bat survey. The use of automated weather meters is strongly encouraged, and it is suggested that more than one unit is deployed per site to allow for equipment failures. Wind speeds from existing turbines or met masts are extremely valuable, and it is important that requests for these data are made to the turbine operator/developer at the start of the project, (accompanied by information on the height at which the data were collected). Note that such data are often only stored on a temporary basis, and so may not be available if data requests are made retrospectively.

5.2.7 *Analysis of results*

Survey data should be collected, recorded and analysed to provide information that can be used to influence the proposals for the site, and to assess the likely impacts of the development throughout the year. Guidance is given below, but see also Collins (2016) and the CIEEM Guidelines for Ecological Impact Assessment for additional information.

6 QUANTIFYING ACTIVITY AND SPECIES VULNERABILITY

The National Bats and Wind Turbines study found that low bat activity at operational sites is useful in identifying sites with low risk of mortality, but found no conclusive link between moderate and high bat activity and risk of mortality. In other words, some sites with low activity had high casualty rates; and conversely a high activity site did not always have high mortality. There is, however, currently no other means of assessing the potential risk posed by a new wind farm to bats therefore bat activity at such sites is considered to be a useful proxy for collision risk.

6.1 ***Assessing bat activity levels***

Standardised data collection (based on static automated detectors) and presentation protocols are vital to provide an objective assessment of bat activity. The following information is required:

1. Location of the detector: either as the latitude and longitude or as an Ordnance Survey or British National Grid reference.

2. Details of the type/model of bat detector used and whether the activity data generated are based on full spectrum or zero-crossing analysis of the sound files.

3. Start and end dates of the survey.

4. Start and end times that the detector was operational in relation to sunset and sunrise.

5. Weather data: wherever possible, weather data should be included for each night that the static detector was deployed. This information should include temperature (recorded from sunset onwards), wind speed, precipitation and if the weather changed during the night. Data should therefore be of a high enough resolution to capture this, e.g. at 10 minute intervals.

6. Microphone height and orientation: the detector will usually be placed on a tripod, pole or on-site structure with the microphone approximately 2m above ground level. Care should be taken to clearly identify surveys undertaken at greater heights e.g. on meteorological masts.

7. Presence (and type) of linear feature within a 50m radius of the detector.

8. Phase 1 habitat classification, e.g. wet heath/dry heath (see JNCC handbook for Phase 1 habitat survey).

9. The total number of bat passes per night, per species (or species group), for all survey nights, and the criteria by which a bat pass was defined and species were identified.

A standardised format for presenting bat activity data is given in Appendix 1.

A measure of relative bat activity can be obtained using the secure online tool *Ecobat* (http://www.mammal.org.uk/science-research/ecostat/) initially designed by the University of Exeter and now hosted and developed by the Mammal Society (Lintott *et al.,* 2018). The tool compares data entered by the user with bat survey information collected from similar areas at the same time of year and in comparable weather conditions. The comparator database is held in a secure repository and includes surveys from the National Bats and Wind Turbine Project and other research studies, as well as data submitted by users. Ecobat generates a percentile rank for each night of activity and provides a numerical way of interpreting the levels of bat activity recorded at a site across regions in Britain. An example of the output is given in Appendix 2. Developers and their consultants are encouraged to make use of this facility because it is currently the most objective method of assessing bat activity. It will also become increasingly valuable to industry the greater the uptake by users: as the size of the comparator dataset grows, it will be possible to make more precise comparisons at higher spatial and temporal resolutions.

Table 1: *Percentile score and categorised level of bat activity*

Percentile	Bat activity
81 to 100	High
61 to 80	Moderate to High
41 to 60	Moderate
21 to 40	Low to Moderate
0 to 20	Low

Survey reports should contain the percentile level (including confidence intervals) and an indication of how this activity should be interpreted (e.g. Moderate to Low, or High[7]). The sample size that the reference range was constructed from (shown in the Ecobat output) should also be presented. Wherever possible, the results should be used at both the local (detector) scale, as this can assist in informing the siting of turbines, and at the site scale to allow assessment of bat activity across the proposed development.

Reports should present information on the activity of individual species (or groups of species with similar call types if it is not possible to distinguish between them with confidence).

[7] The choice of the cut-off points for each category is based on extensive consultation with stakeholders.

Assessments of bat activity that do not use the online repository must detail how the inferred level of relative bat activity has been derived.

6.2 *Vulnerability to collision*[8]

Vulnerability to collision is likely to depend on the location of turbines in relation to bat activity. Bat activity and hence risks are rarely uniform across a site but good coverage of detectors across a site will help in assessing which potential turbine locations present greater risk.

A generic assessment of vulnerability to collision for UK species, based on species behaviour and flight characteristics, is presented in Appendix 3.

Siting turbines within woodland ('key-holing') can present additional risk through the creation of edge-effects attracting greater bat activity, as demonstrated by various studies showing that natural and logged clearings create edges that many species of bat favour. For example, see Kirkpatrick *et al*. (2017) in which *Nyctalus* spp. activity significantly increased following clear-felling of sitka spruce stands. Furthermore, the size of the felled area influenced activity with 90% higher activity in smaller felled stands compared to larger felled stands. The Eurobats guidance also urges caution in this respect, citing the potential risk presented by key-holed turbines to high flying species above the canopy.

These risks will need to be taken into account in an assessment. In addition, there are species-specific differences in the risks linked with habitat types: for noctule bats the presence of woodland is associated with increased risk, whereas for pipistrelles, there is some evidence of lowered risk, although the type of woodland is also relevant here (see National Bats & Wind Turbines Project report).

6.3 *Further considerations*

In addition to the above, consideration should be given to other future changes in land use on the site that may occur as a result of the wind turbine development or during the proposed lifespan of the turbine. For example, a change from arable habitat before construction to cattle pasture following construction could provide higher quality foraging habitat for bats and lead to greater risk of mortality; or mitigation and habitat enhancement for other ecological receptors may attract bats into the area following implementation. Surveys should be designed, where possible, to allow the assessment of any future impacts on bats as a result of a change in habitat management. E.g. assessing bat activity in both closed canopy areas and more open ones which may mimic post-felling, post-construction conditions.

6.4 *Interpreting the results*

Estimating the vulnerability of bat populations to windfarms is based on three factors:

1. Relative abundance (Table 2);
2. Collision risk (Table 2); and
3. Bat activity recorded at the site.

Appendix 3 sets out the potential collision risk for each species based on its behaviour and ecology and evidence of casualty rates in the UK and the rest of Europe. Table 2 uses this measure of collision risk, in combination with relative abundance, to indicate the potential vulnerability of populations of British bat species. The overall potential vulnerability of bat populations is identified as: low (yellow), medium (beige), high (red).

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[8] In this context the term "collision" is taken to mean any form of injury or mortality associated with the operation of wind turbines, i.e. it includes mortality due to barotrauma.

Combining the level of potential vulnerability identified in Table 2 with bat activity recorded at the site can help inform the assessment of potential risk and guide the decision-making process in relation to the mitigation options.

Table 2: *Level of potential vulnerability of populations of British bat species.*
(Adapted from Wray et al., 2010)

Yellow = low population vulnerability

Beige = medium population vulnerability

Red = high population vulnerability

	England	**Collision risk**		
		Low collision risk	**Medium collision risk**	**High collision risk**
Relative abundance	**Common species**	Brown long eared bat		Common pipistrelle Soprano pipistrelle
	Rarer species	Daubenton's bat Natterer's bat Whiskered bat Brandt's bat Lesser horseshoe	Serotine bat	Nathusius' pipistrelle Noctule bat Leisler's bat
	Rarest species	Alcathoe bat Bechstein's bat Greater horseshoe Grey long eared bat	Barbastelle bat	

	Scotland	**Collision risk**		
		Low collision risk	**Medium collision risk**	**High collision risk**
Relative abundance	**Common species**			Common pipistrelle Soprano pipistrelle
	Rarer species	Brown long eared bat Daubenton's bat Natterer's bat		
	Rarest species	Whiskered bat Brandt's bat		Nathusius' pipistrelle Noctule bat Leisler's bat

	Wales	**Collision risk**		
		Low collision risk	**Medium collision risk**	**High collision risk**
Relative abundance	**Common species**			Common pipistrelle Soprano pipistrelle
	Rarer species	Brown long eared bat Daubenton's bat Natterer's bat Lesser horseshoe		
	Rarest species	Alcathoe bat[9] Bechstein's bat Brandt's bat Greater horseshoe Grey long eared bat Whiskered bat	Barbastelle Serotine	Nathusius' pipistrelle Noctule bat Leisler's bat

[9] Presence not yet confirmed within Wales.

6.4.1 *Potential population impacts and Favourable Conservation Status*

As one of the factors determining Favourable Conservation Status (FCS) of a species is geographic range, negative impacts that effectively eliminate a species from a site at the edge of its known range can affect its conservation status[10] even if the number of casualties involved is minor in relation to the total national population size. Therefore, it is important to recognise that a local impact can translate into one of national or international significance if it occurs at the edge of the range[11], or impacts a rare species. This is based on our understanding of population status (adapted from Wray *et al.,* 2010) but may need to be reviewed in the light of the 2018 review of the population and conservation status of British mammals (Mathews *et al.* 2018) see:
http://publications.naturalengland.org.uk/publication/5636785878597632.

Irrespective of this, it is important to note that consideration of FCS applies both at the local and national levels.

7 ASSESSING POTENTIAL RISK AND APPLYING MITIGATION

The mitigation hierarchy indicates that development planning should first seek to avoid significant effects. Where this is not possible, they must be adequately mitigated. Mitigation options should be considered at several stages of development; in the initial site assessment, pre-application, pre-construction (embedded mitigation) and then, if necessary, at the post-construction stage.

Bat activity and the presence of high risk species are not the only factors determining the most appropriate form of mitigation at a site, however; site-based risk factors are also important and must be incorporated within the decision making process. This will require a review of the potential risks that may exist at a proposed wind farm site.

Tables 3a and 3b illustrate the factors to consider when assessing potential risk to bats and present a two-stage process to enable this. Table 3a (Stage 1) gives an indication of potential site risk based on a consideration of habitat and development-related features. An overall assessment of risk can then be made by considering the site assessment in relation to the bat activity output from Ecobat (Table 3b, Stage 2) and taking into account the relative vulnerability of each species of bat present, at the population level, in Table 2.

Note that the values given within Table 3a are *indicative* and not intended to rigidly classify the overall risk of a site, but should be read as a guide to how the various risk categories are to be interpreted. It is important to note that habitats at proposed wind farm sites rarely fall into categories generally considered to be optimal for bats. Indeed, high casualty rates have been observed at upland sites with no local woodlands or linear features, emphasising that great caution must be exercised before concluding that a site is of low suitability for bats.

The output from Stage 1 (i.e. the potential risk level of the site) is used in the matrix in Table 3b to derive an overall risk assessment based on the activity level of high collision risk species. This table is intended to identify those sites which are of greatest concern in terms of potential collision risk, but as apparently low risk sites can sometimes result in bat casualties, caution is

[10] Species range contraction is a dynamic process and more complex than the loss of a species from a single locality on the edge of its known range, but for the purposes of Article 17 reporting it can have consequences in terms of range mapping and hence the recorded conservation status.

[11] On the edge of range population density is generally lower, re-colonisation may only be possible from restricted directions and reproductive rates are likely to be lower. Thus losses at the edge may exceed the capacity for re-colonisation from the species' core distribution.

needed when drawing conclusions. **This exercise should be carried out separately for all high collision risk species recorded on site**. The outputs of the overall risk assessment are then considered in the context of any potential impacts *at the population level* for each of the three species assessed in Table 2 as having high population vulnerability.

Table 3a: *Stage 1 - Initial site risk assessment*

Site Risk Level (1-5)*	**Project Size**			
Habitat Risk		**Small**	**Medium**	**Large**
	Low	1	2	3
	Moderate	2	3	4
	High	3	4	5

Key: Green (1-2) - low/lowest site risk; Amber (3) - medium site risk; Red (4-5) - high/highest site risk.

* Some sites could conceivably be assessed as being of no (0) risk to bats. This assessment is only likely to be valid in more extreme environments, such as above the known altitudinal range of bats, or outside the known geographical distribution of any resident British species.

Habitat Risk	**Description**
Low	Small number of potential roost features, of low quality. Low quality foraging habitat that could be used by small numbers of foraging bats. Isolated site not connected to the wider landscape by prominent linear features.
Moderate	Buildings, trees or other structures with moderate-high potential as roost sites on or near the site. Habitat could be used extensively by foraging bats. Site is connected to the wider landscape by linear features such as scrub, tree lines and streams.
High	Numerous suitable buildings, trees (particularly mature ancient woodland) or other structures with moderate-high potential as roost sites on or near the site, and/or confirmed roosts present close to or on the site. Extensive and diverse habitat mosaic of high quality for foraging bats. Site is connected to the wider landscape by a network of strong linear features such as rivers, blocks of woodland and mature hedgerows. At/near edge of range and/or on an important flyway. Close to key roost and/or swarming site.

Project Size	**Description**
Small	Small scale development (≤10 turbines). No other wind energy developments within 10km. Comprising turbines <50m in height.
Medium	Larger developments (between 10 and 40 turbines). May have some other wind developments within 5km. Comprising turbines 50-100m in height.
Large	Largest developments (>40 turbines) with other wind energy developments within 5km. Comprising turbines >100m in height.

Table 3b: *Stage 2 - Overall risk assessment*

Site risk level (from Table 3a)	Ecobat activity category (or equivalent justified categorisation)					
	Nil (0)	Low (1)	Low-moderate (2)	Moderate (3)	Moderate-high (4)	High (5)
Lowest (1)	0	1	2	3	4	5
Low (2)	0	2	4	6	8	10
Med (3)	0	3	6	9	12	15
High (4)	0	4	8	12	15	18
Highest (5)	0	5	10	15	20	25

The scores in the table are a product of multiplying site risk level and the Ecobat activity category (or equivalent). The activity categories equate to those given in Table 1 for high collision risk species. Nil (0) means no bat activity was recorded across the whole site, but caution is needed here, because although the values given in this column are "0", at sites where pre-construction surveys found no bat activity, there remains the possibility that new turbines could attract some bat species, thereby altering the level of risk that applies in reality.

Overall assessment:

Low (green)	0-4
Medium (amber)	5-12
High (red)	15-25

It is important to have an understanding of both "typical" and unusually high levels of bat activity at a site so that potentially important peaks in activity are not overlooked. It is therefore recommended that both the highest Ecobat activity category and the most frequent activity category (i.e. the median) are assessed separately in Table 3b and presented in the overall risk assessment. A judgement can then be made on which is the most relevant. It should be noted that presenting mean activity levels can be highly misleading where the data are highly skewed, as is frequently the case with bat activity at wind turbines (Lintott & Mathews, 2018).

7.1 *Mitigation options*

Three options for mitigation are described below dependent on the assessed risk to bats. All three options have either been previously described in guidance relating to windfarms and bats, or have direct evidence supporting their efficacy at reducing impacts.

7.1.1 *Adjusting the layout of the turbines*

The risk to bats may be lessened by adjusting the proposed layout of the turbines, in order to avoid parts of the development site that have been shown to have high bat activity and where turbines might pose a particular risk of bat collisions. Where there is little scope for avoiding areas of high risk through micro-siting or a reduction in the number of turbines[12], buffers and/or curtailment mitigation can be put in place (see below).

[12] There is a linear relationship between the number of turbines at a site and increases in the number of bat fatalities (see the National Bats and Wind Turbine Project) which is reflected in the assessment of risk in Table 3a.

7.1.2 *Buffers*

The Eurobats guidance recommends a 200m buffer around woodland areas. There is, however, currently no scientific evidence to support this distance in the UK and it is recommended that a distance of 50m [13] between turbine blade tip and nearest woodland (or other key habitat features such as wetlands etc., see Figure 1) is adequate mitigation in most, lower risk situations. Exceptionally, larger buffers may be appropriate, e.g. near major swarming and hibernation sites. The longevity of wind farms should also be taken into account and the maximum growth, or management, of woodland and other relevant habitat features considered in their planning.

A 50 m buffer distance should be applied as a basic standard mitigation measure for all bat species occurring at proposed wind farms, including all key-holed sites, which may present an increased risk of bat collisions (section 6.2). In practice, the 50m buffer should be applied universally, irrespective of whether curtailment is also considered necessary. Some higher risk species, notably the high-flying ones such as noctules and Leisler's bats frequently fly in open areas however and this form of mitigation is unlikely to be effective for these.

Figure 1: *Estimating buffer distance*

Calculate the distance between the edge of the feature and the centre of the tower (*b*) using the formula:

$$b = \sqrt{(50+bl)^2 - (hh - fh)^2}$$

where:

bl = blade length, *hh* = hub height ,
fh = feature height (all in metres).
For the example shown, *b* = 69.3m[14]

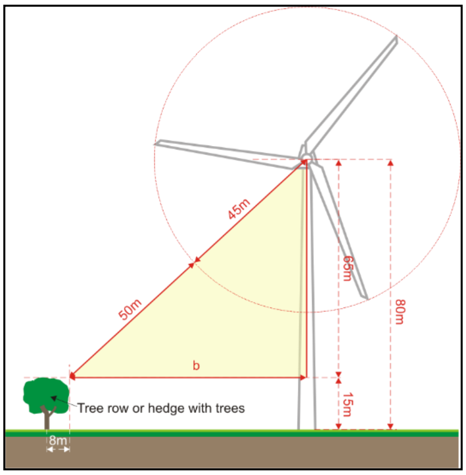

Illustration © Entec Ltd.

7.1.3 *Strategies to reduce mortalities by altering blade rotation*

There is evidence that bat casualties at wind farms is reduced by pitching the blades out of the wind ("feathering") to reduce rotation speeds below 2 rpm while idling, and in some cases increasing the cut-in speed during high risk periods (i.e. warm evenings in summer with low wind speeds) e.g. Arnett *et al*., 2013. The practical application of these two forms of turbine manipulation is discussed below.

(a) Reduced rotation speed while idling

The reduction in speed resulting from feathering compared with normal idling may reduce fatality rates by up to 50%. As this option does not result in any loss of output**, as best practice, it is recommended wherever it is practically possible and there remains uncertainty over**

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[13] The evidence in Britain is that most activity is in close proximity to habitat features. Activity was shown to decline when measured at fixed intervals up to 50m away from treelines and at varying intervals up to 35m from treelines (Verboom & Spoelstra 1999; Downs & Racey 2006).

[14] If the feature is a watercourse or other waterbody and is at, or below the horizontal level to the turbine base, the value for feature height (*fh*) is assumed to be zero. In this example *b* would then be 51.2m.

the risk posed to bats. It can be applied at *any* site with a blade pitch control system which can be automated using SCADA data.

(b) Curtailment

This involves raising the cut-in speed with associated loss of power generation in combination with reducing the blade rotation below the cut-in speed, as above. It should be considered where feathering below cut-in normal speed (above) will not provide sufficient reduction in risk to bats. The curtailment is achieved by feathering (not the actual braking of the turbine) so that the blades continue to rotate slowly (at ~2 rpm or less).

The most basic and least sophisticated form of curtailment - "blanket" curtailment - involves feathering the blades between dusk and dawn over the entire bat active period (April to October). This is achieved on some turbines by setting the operating mode to "pause" for these specified periods. However, this strategy is inefficient and results in considerable unnecessary down time for the turbines concerned. A more sophisticated solution is to focus on certain times and dates, corresponding with those periods when the highest level of bat activity is expected to occur. Further savings can be achieved by programming the SCADA[15] operating system to only pause/feather the blades below a specified wind speed and above a specified temperature within specified time periods. This approach is very effective if bat activity can be accurately modelled from environmental data. However, for sites where bat activity is unpredictable this approach may not be effective. Another possible option that has been trialled on an experimental basis is to use continual acoustic monitoring at nacelle height using full spectrum static bat detectors which supply real-time bat activity data to the control system which is also receiving real-time weather data. These parameters are continually monitored on site and the data generated can be analysed in relation to bat activity data. Thus, the periods of high bat activity can be identified in relation to key weather parameters.

In order to minimise down time, the threshold values at which turbines are feathered should be site specific and informed by bat activity peaks at that location, but as an *indication*, they are likely to be in the range of wind speeds between 5.0 and 6.5m/s and at temperatures above approximately 10 or 11ºC measured at the nacelle. Significant savings can be achieved by so-called "smart" curtailment over the other less sophisticated alternatives.

An example case study of how curtailment has been implemented (post construction) at a UK operational wind farm site is given in Appendix 5. The approach taken here is recommended more widely within the industry both in respect of taking remedial action in response to an identified problem, but also as an example of how to develop and optimise a curtailment regime and associated control system utilising weather data.

The effectiveness of curtailment needs to be monitored in order to determine (a) whether it is working effectively (i.e. the level of bat mortality is considered to be incidental), and (b) whether the curtailment regime can be refined such that turbine down-time can be minimised whilst ensuring that it remains effective at preventing casualties.

Where the need for curtailment has been identified, a curtailment regime should be developed and presented as a part of the supporting Environmental Statement for the project. The proposed operating regime should specify, and be designed around the values for the key weather parameters and other factors that are known to influence collision risk which may include any or all of the following:

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[15] SCADA: Supervisory Control and Data Acquisitions

- Wind speed in m/s (measured at nacelle height)
- Time after sunset
- Month of the year
- Temperature (ºC)
- Precipitation (mm/hr)

Preliminary site-based thresholds for the above can be derived from acoustic bat activity data recorded on static detectors during the pre-construction acoustic surveys. These data can be used to identify the range of wind speeds and temperatures favoured by different bat species at a particular site – information that can then be used in conjunction with seasonal and nightly bat activity data to inform the operation of the turbines. The more efficient the model is at utilising the available weather data within the algorithm that determines turbine curtailment, the more effective it is likely to be at both preventing bat casualties and minimising turbine downtime. Operating parameters should be agreed through the planning permission, while allowing scope for adjusting the curtailment where post-construction monitoring provides evidence of a reduced (or increased) risk to bats.

8 POST-CONSTRUCTION MONITORING

Post-construction monitoring is normally only required at developments where the mitigation involves turbine curtailment. It should aim to assess changes in bat activity patterns and the efficacy of mitigation to inform any changes to curtailment. Monitoring should take place for at least 3 years[16] after construction, but the effects of habitat modification and off-site enhancements on bat activity may require monitoring over a longer period.

Post construction monitoring also has wider benefits in improving our overall understanding of how bats interact with wind turbines and how we can minimise impacts across all wind farm sites.

8.1 *Monitoring curtailment*

In order to evaluate the success of the curtailment regime, a minimum of 3 years of monitoring should take place during which time casualty searches and acoustic monitoring should take place concurrently. If necessary, over this period the curtailment regime can be refined to "smart curtailment" informed by the weather data and bat activity data, as described above (section 7.1.3). This can be an adaptive process as illustrated by the case in Appendix 5.

8.1.1 *Bat activity monitoring*

Acoustic surveys can be used to continue to assess bat activity and behaviour following construction of turbines to assess the ongoing need for curtailment mitigation. For example, it may be that the construction of wind turbines significantly reduces bat activity at the site relative to that recorded pre-construction and to a level at which there is no longer a need for curtailment. Alternatively, the reverse of this scenario cannot be dismissed, i.e. where bat activity increases on site post-construction, as there is some evidence of attraction amongst some bat species to wind turbines (Richardson *et al.,* in prep.). Initial assessments of the level of risk at a site can therefore prove unreliable and there are examples of apparently low risk sites (including afforested upland sites planted with commercial conifers), where repeated bat casualties have subsequently been recorded (e.g. Lintott *et al.*, 2016).

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[16] The minimum of 3 years do not necessarily have to be consecutive, but the total monitoring period should be sufficient to detect any significant change in bat activity relative to pre-construction levels.

Post construction acoustic surveys provide additional information which, when used in conjunction with appropriate carcass search data, can support any proposed changes to pre-application predictions concerning the need for curtailment or adjustments to an agreed curtailment regime. Section 5 sets out methods for acoustic surveys. Where post construction acoustic surveys are undertaken, they should utilise full spectrum automatic detectors deployed, as a minimum, for the same duration as during pre-application surveys and at the same density. They should cover one complete bat activity season. Acoustic monitoring can be supplemented with thermal imaging cameras etc. as necessary to provide more detailed information on bat activity in the vicinity of turbines, as necessary.

Nacelle-level surveys can provide additional post construction activity data and can be used to supplement ground-based equipment designed to replicate the survey effort undertaken at the pre-application stage (see Roemer *et al.,* 2017). They may be particularly useful at woodland key-holed sites, especially where there is evidence of a high level of Nyctaloid bat activity above the tree canopy and within the height of the rotor-swept area which could be missed using ground-based equipment.

8.1.2 *Carcass searching*

Post construction casualty searches provide a baseline against which to measure the success of subsequent curtailment measures.

Systematic searches for bat casualties on the ground below wind turbines (focusing on the hard standing) are currently the only effective means of monitoring bat fatalities. It should be noted that the habitats below most turbines in the UK, including ploughed soil, rubble and some types of hard standing, as well as more obviously challenging environments such as clear-felled areas and heathland, present difficult search conditions.

Carcass searching at its most basic simply involves looking out for casualties of bats (and birds) underneath the turbine blades. Such searches can be carried out by appropriately trained operational staff and may be useful in identifying if an issue with bat fatalities exists at a site, provided the nature of the search area is such that casualties, if present, are likely to be detected. Searches of this type are *not* a substitute for the more intensive method, detailed in Appendix 4, designed to quantify casualty rates should an issue with bat fatalities be identified.

Searches should be undertaken as early as possible in the morning during high risk periods. Such periods could be informed by the results of pre-application activity surveys. At upland sites, accurately predicting high risk periods can be particularly challenging because they are likely to be brief and highly weather-dependent; warm, dry nights in summer with high insect abundance may result in unusually high levels of bat activity, such that the following morning would be the time to undertake a carcass search. This may not always be practical for a variety of reasons, but focusing effort in this way helps to ensure that high risk periods are monitored and the effects of carcass decay and scavenging are minimised (Appendix 4). It should be recognised in any assessment that searches undertaken in optimum conditions may provide a biased result in terms of the frequency and extent of mortality, unless the analysis accounts for this potential source of bias, e.g. by estimating the number of nights with such optimum conditions relative to those with sub-optimal and poor conditions, using the available weather data.

It is essential that casualty searches use a method with high observer efficiency. It must be noted that in almost all circumstances, the number of bats to be detected at an individual turbine will be low (fewer than 3 per month). Therefore if the observer efficiency is low, then it is unlikely that casualties will be detected. Suitably trained dogs with handlers are significantly more efficient and faster than humans in locating carcasses and should preferably be used to achieve more robust results. The methodology for this was developed at Exeter University and is detailed in Appendix 4. (See also Appendix 4 of the report on the National Bats and Wind Turbines study). Dog searches are, however, resource-demanding and may not always be necessary to identify if a problem exists.

There may be some circumstances where it is not possible to use search dogs e.g. in a water treatment works; or where observer efficiency by humans is acceptable (e.g. where the sward is tightly mown). Methods with an observer efficiency of <50% are not acceptable because of the substantial risk of false-negative results (see Appendix 4).

It is essential that the carcass removal rate by predators is also quantified. At many sites, almost all casualties are removed within a few days of collision. To some extent, this error can be compensated for if the carcass removal rate is known. However it is also important to note that the impact of carcass removals can be particularly problematic where there are long intervals between searches, because all casualties may be removed before a search takes place. It is therefore generally more efficient to group carcass searches into intensive blocks, rather than to spread occasional searches across the entire active season.

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Glossary

*Automated bat detector***:** a system for recording bat echolocation calls that can be left unattended in the field.

Commuting: the flight of a bat between a roost and a feeding area, or between two feeding areas, or two roosts.

Cumulative effect: combined effect on the environment caused by a proposed development, in conjunction with other past, present and reasonably foreseeable developments and other human activities.

Curtailment: the act of limiting the supply of electricity to the grid during conditions when it would normally be supplied. This is usually accomplished by cutting-out the generator from the grid and/or feathering the turbine blades.

Cut-in speed: the wind speed at which the generator is connected to the grid and producing electricity. The manufacturer's set cut-in speed for most contemporary turbines is between 3.0 and 4.0 m/s. For some turbines, their blades will spin at full or partial RPMs below cut-in speed when no electricity is being produced.

Feathering or feathered: adjusting the pitch of the rotor blade parallel to the wind, or turning the whole unit out of the wind, to slow or stop blade rotation. Normally operating turbine blades are angled perpendicular to the wind at all times.

Idling: blades that rotate below cut-in speed and therefore not generating power. In contrast, blades can be "locked" and cannot rotate, which is a mandatory situation when turbines are being accessed by operations personnel.

Increasing cut-in speed: the turbine's computer system (referred to as the Supervisory Control and Data Acquisitions or SCADA system) is programmed to a cut-in speed higher than the manufacturer's set speed, and turbines are programmed to stay feathered at 90o until the increased cut-in speed is reached over some average number of minutes (usually 5–10 min), thus triggering the turbine blades to pitch back "into the wind" and begin to spin normally.

Migration: regular, usually seasonal, movement of all or part of an animal population to and from a given area.

Mitigation: action taken to mitigate, reduce or minimise any negative environmental impact such as habitat loss, animal fatality or injury where it is not possible to avoid such impacts.

Re-powering: increasing the generating capacity of a wind turbine site by fitting more efficient generators or blades to existing turbines, or replacing existing turbines with newer more efficient turbines. As technology has improved there is a general trend to replace older smaller turbines with fewer more efficient larger turbines.

Swarming: "autumn swarming" by some species of vespertilionid bats (particularly *Myotis, Plecotus, Eptesicus* spp. and *B. barbastellus*) occurs from late summer to autumn. *P. auritus* performs a "spring swarming" as well. Bats may travel many kilometres to underground "swarming sites", arriving several hours after dusk, and flying in and around the site and departing before dusk. Some swarming sites may also be used as hibernacula later in the year. Swarming ("dawn swarming") also refers to the circling flight pattern of some bat species that occurs outside the entrance to a roost (especially maternity roosts) before the bats enter at dawn.

Appendix 1: Recommended standard format for presenting bat activity data (example given for a site with 3 detectors in use)

Surveying period[1]	Nights of appropriate weather conditions[2]	Detector i.d.[3]	Maximum bat activity (bat passes per night)[4]	Maximum bat activity level (low, moderate, high)	Average bat activity (mean or median bat passes per night)[5]	Bat activity level (Low, Moderate, High)[6]
Spring		A				
Spring		B				
Spring		C				
Summer		A				
Summer		B				
Summer		C				
Autumn		A				
Autumn		B				
Autumn		C				

Notes

1. Distinguishing between surveying period (i.e. seasons) is only relevant if there are demonstrable differences in bat activity between seasons and this may impact mitigation options (i.e. if bat activity only occurs in autumn than it could be argued that the majority of post-construction bat surveys should be conducted in Autumn).

2. 'Appropriate' weather as defined within guidance

3. The example shown involves 3 detectors: A, B and C. Distinguishing between detectors is only relevant if there are demonstrable differences in bat activity between locations and this may impact mitigation options (i.e. demonstrating that bat activity is constrained to one location within the proposed site where curtailment may be considered).

4. Important to illustrate any peaks in activity where collision risk will be highest.

5. The normality of the dataset should be tested: usually the median will be the most appropriate metric to report.

6. This can be based upon consultant expertise (whereby justification for each of the activity levels should be made) or by using *Ecobat* to provide a quantitative assessment (whereby sample size of reference range should be presented)

Appendix 2: Worked example of the bat activity output from Ecobat

Ecobat uses percentiles to provide a numerical representation of activity levels relative to the surrounding landscape for each night of surveying. Percentiles can then be assigned to activity categories (low, moderate, high) to provide a quantifiable measure of bat activity.

Step 1: Data collection & input

Acoustic monitoring for bats was conducted from 4th August until 11th August 2016 at the planned locations of four turbines: T1, T2, T3, T4. Results were entered into the Ecobat pro-forma (below) and uploaded at http://www.mammal.org.uk/science-research/ecostat/. Supplementary data (e.g. weather data) are also welcomed.

Location of bat detector (geographic coordinates)	Location Name	Spatial reference system	Sensitivity of data	Date of bat survey	Species	Passes per night	Bat pass definition	Bat detector make	Bat detector model
50.640032, -3.854916	T1	Latitude/Longitude	Do not publish	04/08/2016	*Pipistrellus pipistrellus*	280	Pass 1s gap	Wildlife Acoustics	SM2
50.640032, -3.854916	T1	Latitude/Longitude	Do not publish	04/08/2016	*Nyctalus noctula*	49	Pass 1s gap	Wildlife Acoustics	SM2
50.640032, -3.854916	T1	Latitude/Longitude	Do not publish	05/08/2016	*Pipistrellus pipistrellus*	38	Pass 1s gap	Wildlife Acoustics	SM2
50.640032, -3.854916	T1	Latitude/Longitude	Do not publish	05/08/2016	*Nyctalus noctula*	16	Pass 1s gap	Wildlife Acoustics	SM2

Step 2: Data analysis & output

The reference range dataset was stratified to include:

- Only records from within 30 days of the survey date.
- Only records from within 100km^2 of the survey location.

Table 1: Median and maximum percentiles for each species at each detector location.

Location Name	Species/Species Group	Median Percentile (±CI)	Max number of passes per night	Max percentile	Number of records compared against
T1	*N. noctula*	37 (33, 40)	61	51	8,120
T1	*P. pipistrellus*	79 (62, 89)	280	92	12,429

Table 2: Nights of acoustic monitoring contained within each activity category.

Location Name	Species/Species Group	Nights of activity				
		High	Moderate/High	Moderate	Low/Moderate	Low
T1	*N. noctula*	0	0	2	5	1
T1	*P. pipistrellus*	4	2	0	2	0

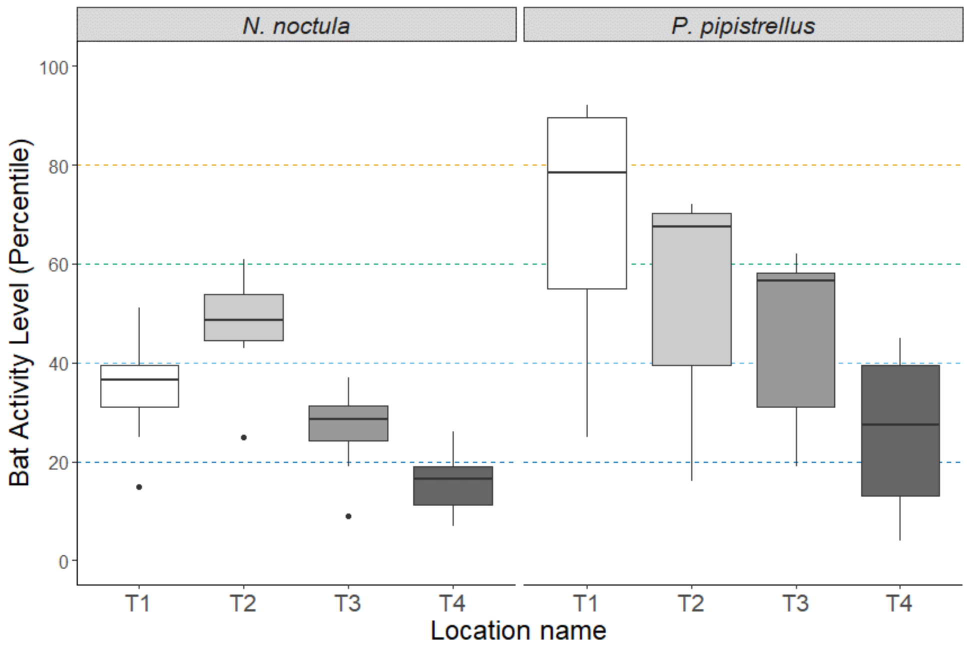

Figure 1. Differences in bat activity between static detector locations. The centre line indicates the median activity level whereas the box represents the interquartile range (the spread of the middle 50% of nights of activity)

Appendix 3: Categorising which bat species are potentially most vulnerable to collision based on physical and behavioural characteristics (and also based on evidence of casualty rates in UK and the rest of Europe).

	Risk of turbine impact		
Factor	Low Risk	Medium Risk	High Risk
Habitat preference	Bats preferring cluttered habitat	Bats able to exploit background cluttered space	Bats preferring to use open habitat
Echolocation characteristics	• Short range • High frequency • Low intensity • Detection distance ~15m	Intermediate – more plastic in their echolocation[17]	• Long range • Low frequency • High intensity • Detection distance ~80m[18]
Wing shape	• Low wing loading • Low aspect ratio • Broadest wings	Intermediate	• High wing loading • High aspect ratio • Narrow wings
Flight speed	Slow	Intermediate	Fast
Flight behaviour and use of landscape	• Manoeuvre well • will travel in cluttered habitat • Keeps close to vegetation • Gaps may be avoided	Some flexibility	• Less able to manoeuvre • May avoid cluttered habitat • Can get away from unsuitable habitat quickly • Commute across open landscape
Hunting techniques	• Hunt close to vegetation • Exploit richer food sources in cluttered habitat • Gleaners	• Hunt in edge and gap habitat • Aerial hawkers	• Less able to exploit insect abundance in cluttered habitat • Aerial hawker • Feed in open
Migration	Local or regional movements.	Regional migrant in some parts of range	Long-range migrant in some parts of range
Conclusion	*Myotis* spp. Long eared-bats Horseshoe bats	Serotine Barbastelle	Common pipistrelle[19] Soprano pipistrelle Noctule Leisler's bat Nathusius' pipistrelle

[17] Except barbastelle

[18] Except *Pipistrellus* spp.

[19] In the previous Natural England TIN051 guidance, both common and soprano pipistrelles were assessed as being medium risk species. However, based on the evidence from the National Bats & Wind Turbines study and Eurobats data, they have been re-assessed as high risk, even though some of the above factors associated with high risk species do not apply.

Appendix 4: Recommended methodology for more intensive studies of mortality rate at turbines

The methodology detailed below is not essential for the carcass searches described in Section 8 of this guidance, but is recommended where *more detailed investigations* are required, e.g. to quantify the mortality rate at a site where a potential problem has been identified.

Frequency of searches and number of turbines to be searched

It is recommended that systematic searches should be conducted within a 100m x 100m grid centred on the turbine, although the exact protocol for carcass searches will vary given the precise objectives of the surveys (i.e. survey may be targeted at particular times of year or locations). It is recommended that at least two search periods (summer and autumn) are used. Spring should also be included if there is particular reason to do so, for example if there are multiple casualties during other survey periods, or the development is thought to be on a migratory route. For a given amount of resource available for carcass searches, there is a trade-off between search frequency and the time period that can be monitored. The longer the inter-search interval, the greater the likelihood of the bat being predated before it is found. It is also difficult to estimate the date of death for bats identified at a first 'sweep' of a site. Therefore one-off searches and long inter-search intervals (e.g. weekly) are not recommended.

Daily searches are recommended at sites with high predation rates or where the observer wishes to link casualty events with weather or acoustic data (in order to refine mitigation). At other sites, searches at 2-4 day intervals are acceptable, based on the predation rates observed at most locations in the National Bats and Wind Turbines study. Data must be obtained from the turbine operators on whether or not the target turbine was operational on the night preceding the search, with the surveying protocol being adjusted as necessary if the turbines were either non-operational or were not rotating because of a lack of wind.
To maximise the duration of monitoring during each season, whilst maintaining low carcass removal rates, it is suggested that surveying can be split into blocks as illustrated below.

Days 1-10	Days 11-20	Days 21-30	Days 31-40	Days 41-50	Days 51-60
Initial 'sweep' then survey alternate days (d2, d4, d6, d8, d10)	No Survey	Initial 'sweep' then survey alternate days	No survey	Initial 'sweep' then survey alternate days	No survey

The number of turbines surveyed should be proportional to the size of the site. At small sites (≤5 turbines), all turbines should be surveyed. At larger sites, the turbines should be a random selection of those available, except where there is good evidence to expect particularly elevated risk in particular locations. Note that the research available to date in the UK from the National Bats and Wind Turbines study suggests a random distribution of casualties across the areas monitored.

One of the major barriers to conducting casualty surveys is lack of appropriate access to the land beneath the turbine. Therefore in selecting sites for survey, it is essential that access is secured at the planning stage of the development and that land-use is conducive to searching. For example, surveys are difficult if not impossible in sites planted with tall crops such as field beans or maize, or in fields close to harvest for hay or silage.

Searcher efficiency trials

Searcher efficiency trials should be conducted at each site to provide appropriate correction factors. This is necessary whether the searches are conducted using trained dogs or human observers. The trials should ideally use dead bats, however if unavailable, similar coloured mammals of equivalent size can be used. The exact methods used should be documented, but it is recommended that at least 10 carcasses are used, as otherwise the correction of casualty rates becomes very coarse (missing just 1 bat out of 5 would substantially influence the correction factor). The carcasses should be dropped from waist height at randomly selected points in similar habitat to that searched under turbines. The person placing the bats must not be involved in the search, and should not reveal the exact number of bats to the observer until the trial is concluded. Care must be taken to avoid creating unrealistic densities of dead bats as this will, in itself, influence searcher efficiency and may also draw predators into the area. Several search plots may therefore be required. Ideally, the efficiency trials will take the form of integrated surveys, where a small number of bats are positioned at each of several turbines (for further details see below), as this provides the most field-realistic assessment. The carcasses should be marked to avoid confusion with turbine-related fatalities, for example by using a dark-coloured cable tie, or by cutting a notch in the ear.

When conducting observer efficiency trials for dog search teams, care should be taken to avoid transferring human scent to the specimen, for example by using tongs or disposable gloves. To allow human scent from footprints to dissipate, an interval of at least an hour should be left between placing the bats and conducting the searcher efficiency trial.

Scavenger removal rates

Bat carcasses are scavenged not only by vertebrate predators but also by insects and burying beetles. The latter are able to remove carcasses completely over the course of one or two days, and are a particular issue in upland and boggy sites. Evidence from the National Bats and Wind Turbines study and European studies indicates that approximately a third of bat carcasses are removed (by invertebrates, mammals or birds) in the first few days, a third remain for more than a month, and the remaining third take variable periods to disappear.

Ideally dead bats should be used for scavenger removal trials although similar size and coloured (or parts of) mammals may prove a suitable substitute if bat carcasses are not available. The carcasses should be marked using a black cable tie, or by cutting a notch in the ear, to avoid confusion with turbine-related fatalities. It is advised that 10 carcasses are used in order to generate robust estimates of true rates. They should be positioned in known locations on a marked out grid the same size as the search area beneath the turbine. To avoid drawing predators into an area by creating a super-abundance of prey, no more than 5 carcasses should be used within any 100m x 100m area, and ideally integrated carcass surveys should be used (see below). Carcasses should be placed out at dusk (or before daylight) as scavenging is greatest at dawn and this approach simulates the time at which turbine-linked fatalities would become available to predators. Care should be taken to avoid transferring human scent which might influence predator behaviour.

The time period over which predator removal rates are checked should correspond with the design of monitoring for casualties. Ideally, search intervals will be short (2-4) days and checks should be conducted whenever carcass searches are conducted (or, preferably, daily as this will help allow trends to be interpolated for missing days). If longer search intervals are used then carcass removal rates will need to be monitored over correspondingly longer periods. If carcass surveys are conducted in time-blocks, then new estimates of carcass removal rates are required for each block. As an alternative to the above protocol, integrated carcass monitoring can be conducted (see below).

Integrated carcass monitoring

Integrated carcass monitoring is recommended as an improvement over plot-based scavenger removal and observer efficiency trials. Using this approach, small numbers of bats (1-2 per turbine) are randomly distributed among all the turbines to be searched. The bats are identified (e.g. using an ear-notch) so that they can be distinguished from turbine-related casualties. The trial bats are then recorded during the routine searches at each study turbine. This approach gives a more realistic estimate of correction parameters as the trial has been conducted across all the habitats included in the project. It also provides observers with multiple opportunities to find each carcass, unlike the plot-based approach to assessing observer efficiency, and there is a lower probability of artificially inflating predator activity at the site. However, integrated surveys need searches to be conducted at frequent intervals (ideally daily or alternate days) and for a sufficient period to enable decay/removal curves to be calculated.

Calculating casualties across a site

As only a proportion of turbines within each site is likely to be sampled, and the number of carcasses found will be an underestimate owing to predator removal and surveying error. Nevertheless, it is possible to obtain an ‘estimate of total carcasses per site per month’ as follows:

(a) If searches are conducted daily, site-level fatalities are calculated thus:

$$True\ n\ killed = \frac{number\ found}{observer\ efficiency\ x\ (1 - predator\ removal\ rate)\ x\ turbine\ search\ rate}$$

Worked example

If 2 bats are found; observer efficiency is 75%; predator removal rate in the first day of predator removal trials is 20%; and 50% of the turbines are searched then:

$$True\ n\ killed/day\ \frac{2}{0.75\ x\ (1 - 0.2)\ x\ 0.5}$$

$$True\ n\ killed/day = 6.66$$

This process would be completed for each daily survey, and the sum of the estimates for the true number killed per day is the site-level fatality estimate.

Clearly the estimates become more precise (i.e. have less error) the higher proportion of turbines are searched. If it is not possible to search all turbines, then those selected should be a random selection of those available. An exception could be where the sampling scheme has specifically been stratified to include turbines identified as being at higher risk — for example on the basis of prior casualty observations, or because they are on a known flight-route, as well as ‘normal risk’ turbines. If sampling is not random, then the estimates need to be computed separately for each stratum (e.g. ‘high risk’ and ‘normal risk’ turbines). Because of the implications for sample size, and the lack of a sound evidence base to identify high-risk turbines in most situations, random sampling is generally the preferred methodology.

Account should be taken of variability in observer efficiency: even using search dogs some habitats will be easier to search than others, and therefore it is vital that the observer efficiency trials are conducted in habitat similar to those beneath the turbine. Ideally, the observer efficiency should be monitored in all habitat types to be encountered, and the estimates should be adjusted accordingly.

(b) If searches are conducted less frequently than daily, site level-fatalities are calculated thus:

Predator removal rates must be computed for the relevant time period since the previous search. For example, if searches are conducted on days 1 and 4, the inter-search interval is 3 days (a casualty found on day 4 may have been killed on night 1, night 2 or night 3).

Worked example

Surveys were conducted on 1st July and 4th July, yielding 1 and 3 carcasses respectively. These surveys were preceded by a 'sweep' of the site on 30th June to remove any existing carcasses (data discarded) and to put out test bats for monitoring. Predator removal monitoring was conducted on the same days as the site was visited to search for turbine casualties.

The above survey schedule gives inter-search intervals of 1 day and 3 days.

Observer efficiency is 75%. Half of the turbines are searched and predator removal rates are as follows: 25% 1st July; 15% 4th July (i.e. cumulatively, 40% have been removed).

$$True\ n\ killed = \frac{number\ found}{observer\ efficiency\ x\ (1 - predator\ removal\ rate)\ x\ turbine\ search\ rate}$$

For the first search interval (1 day), calculations are conducted as in example (a).

$$True\ n\ killed/day\ \frac{1}{0.75\ x\ (1 - 0.25)\ x\ 0.5}$$

$$True\ n \frac{killed}{day} = 3.6$$

For the 2nd search interval (3 days), the bat could have died any time between 1st July and 4th July, so the median number of days is used i.e. 1.5 days. We do not have a direct estimate of the casualty rate on day 2, so substitute the next available estimate. Note that where removal rates are highly variable, or where inter-search intervals are long, it is recommended that data are plotted to generate decay curves, and the relevant removal rates are read from the curves. However, for short inter-search intervals, the approach followed below is a reasonable substitution.

$$predator\ removal\ rate = day\ 1\ rate + 0.5\ x\ day\ 2\ rate = 0.25 + 0.075 = 0.33$$

$$True\ n\ killed\ across\ 3\ days = \frac{3}{0.75\ x\ (1 - 0.33)\ x\ 0.5} = 11.94$$

Mean casualty rate per day across the survey period

$$True\ n\ killed\ across\ 4\ days = 3.6 + 11.9$$

$$True\ n\ killed/day = \frac{15.5}{4} = 3.9$$

Consideration should be given to using median rates rather than means if the observed collision rates are highly variable between days, as they are less prone to inflation by exceptional datapoints.

It is preferable to conduct predator removal studies throughout the study period, since predation rates may change over time depending on weather and other variables. It would therefore be difficult to extrapolate predator removal rates observed on 1st July, for example, to casualties found on 15th August.

Other methodological considerations

For any bat casualties found the following information should be recorded: time, date, location (GPS), visible injuries, species and sex (if possible). Specimens should also be photographed. Unless being used as part of a carcass removal study, bats should be collected, stored and frozen to allow subsequent DNA confirmation of species. Such data should be provided to the relevant SNCO to assist with reporting requirements under the Eurobats Agreement and the EC Habitats Directive (Article 17). Note that the possession and collection of dead bats requires a licence from the appropriate SNCO.

Appendix 5: Case study of operational curtailment implementation

Introduction

Curtailment mitigation has been implemented at a large (>100MW) windfarm in response to new evidence on the frequency of bat fatalities which emerged during site operation. The site occupies the upland zone above 200m altitude and comprises a mixture of forestry plantation, felled plantation and existing moorland habitats.

Methodology

In order to determine whether curtailment would be effective at reducing bat fatalities, and if so what parameters should be used, a study was designed to investigate the pattern of bat activity at the site temporally, spatially and in response to weather conditions. Bat activity was measured at n=18 turbines continuously between July and September in Year 1 in combination with carcass surveys. In addition, wind speed and temperature data were continuously recorded at nacelle height.

In Year 2, curtailment was activated at the site using parameters determined from Year 1 data, with bat activity data collected from n=12 locations continuously between April and mid-October in combination at carcass surveys at n=24 locations.

Results

Over 95% of recorded passes on the site comprised 3 species: soprano pipistrelle (56.6%); common pipistrelle (35.5%); and noctule (3.8%).

There was a strong pattern of seasonal temporal variability in bat passes, with most activity occurring between the mid-August to mid-September period (Figure 1).

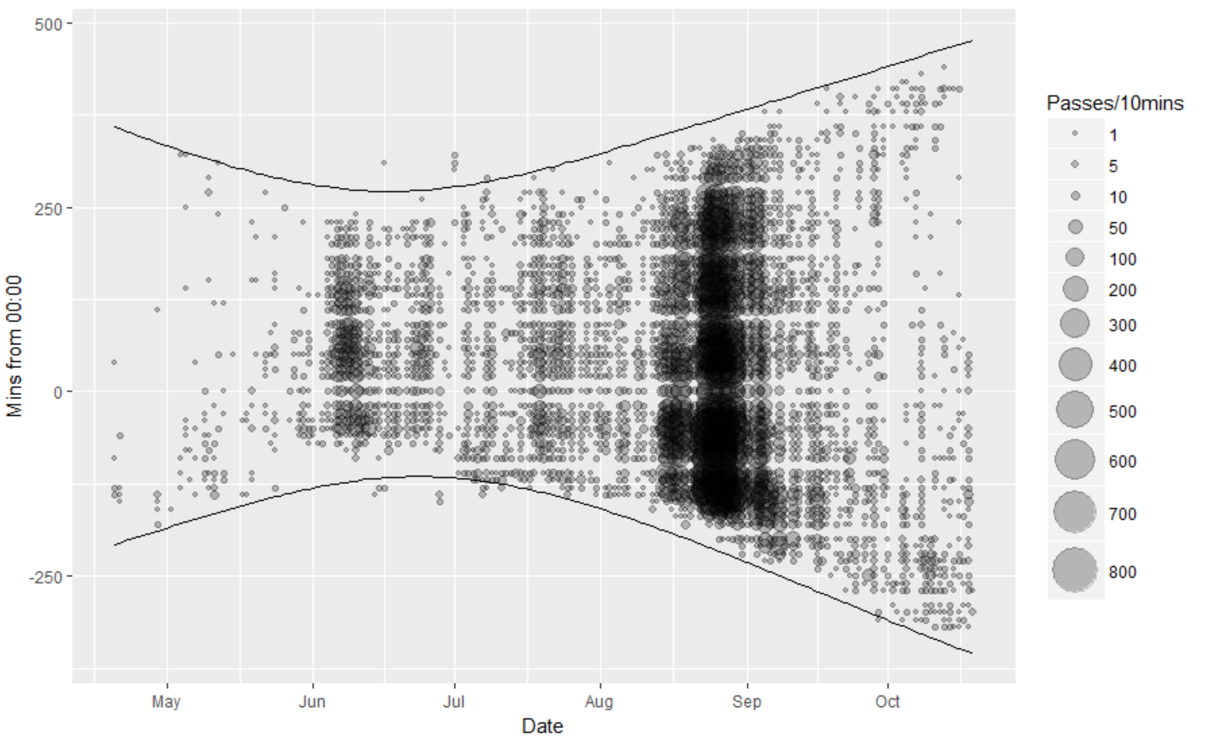

Figure 1: Total number of all bat passes recorded in Year 2 in each 10 minute period at n=12 locations. The upper and lower solid lines represent sunrise and sunset respectively. A similar pattern was recorded in Year 1.

There were no discernible spatial patterns in recorded bat activity or fatalities within the site. Temperature and wind speed were significant factors (both $p<0.001$) associated with recorded bat passes (adjusted R-squared 0.5). A plot of the raw activity data with corresponding nightly temperature and wind speeds is shown in Figure 2.

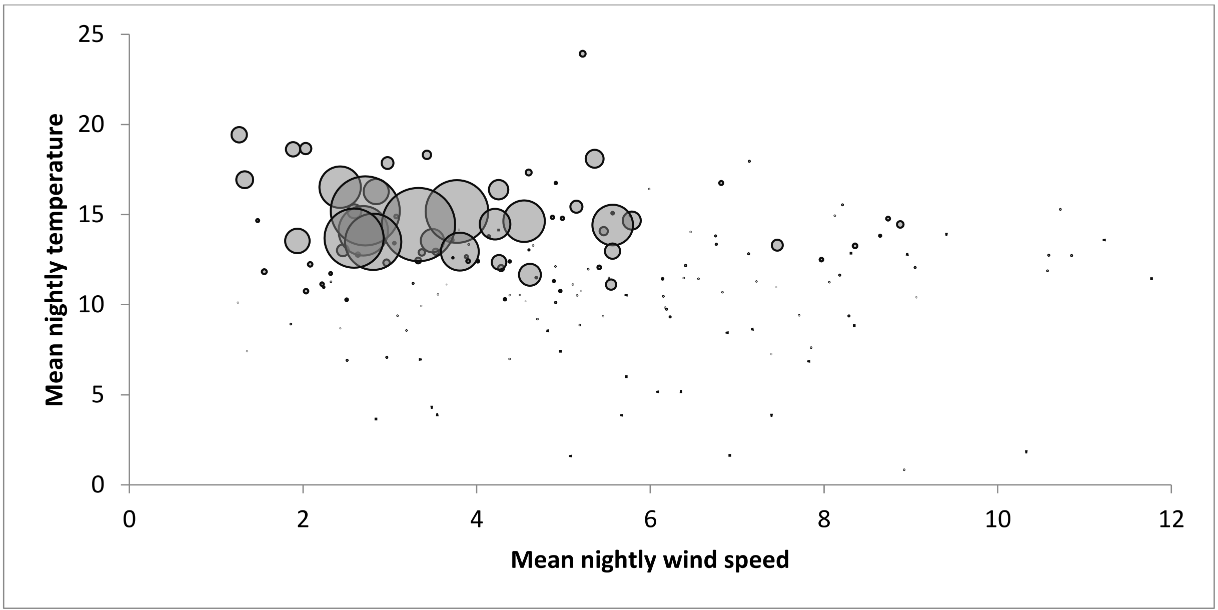

Figure 2: Relative abundance of recorded bat passes plotted against corresponding mean nightly wind speed and temperature.

Curtailment strategy

After Year 1 it was calculated that 90% of all bat activity occurred on the site when temperature exceeded 11.5°C and windspeed was below 5m/s. In addition, the first bat passes were recorded 30min after sunset and the last bat passes were recorded 40min prior to sunrise. As such a software module was programmed into the SCADA system controlling the turbines to curtail turbines when all of these criteria were met. Curtailment is achieved by opening the blade pitch into the fully-feathered position, which reduces blade rotation speed to <1rpm.

Following activation of this system, no bat carcasses were detected at any of the curtailed turbines during Year 2. Given the high probability of carcass detection using trained dog teams it can be concluded with high confidence that the total number of bat fatalities is either zero or so close to zero to be undetectable.

The performance of the system in terms of its ability to respond to the changes in bat abundance based on temperature and wind speed was analysed to confirm it was neither significantly over- nor under- curtailing during different periods of bat activity. Since individual turbines are subject to variation in ambient temperature and wind speed at any given time the whole site will be curtailed for a variable percentage of the available operational time during the night depending on the weather. The percentage of the available operating time within a night the site was curtailed and the corresponding level of bat activity in is shown below in Figure 3. The linear regression has an R-squared value of 0.57, which suggests the curtailment parameters are a good predictor of bat activity, with no points in the extreme bottom-right or top-left areas which would give concern as they would represent significant over- or under-curtailment respectively.

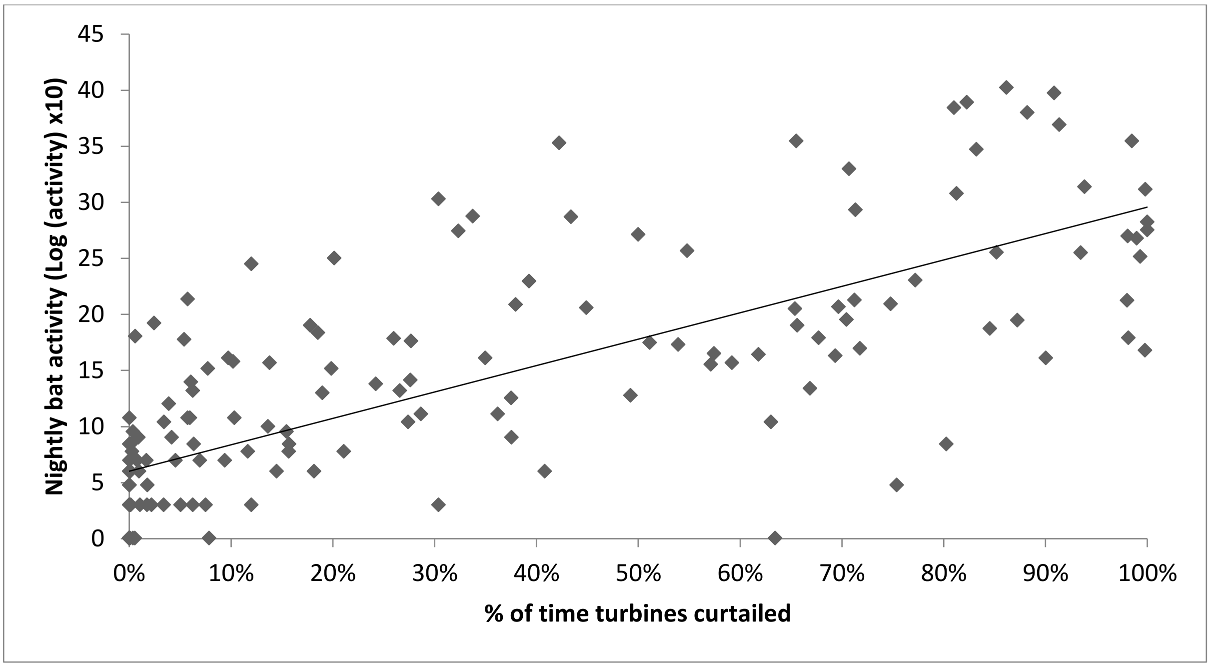

Figure 3: Scatterplot % time all turbines were curtailed on a single night against the recorded number of bat passes during the same period. The solid line is a simple linear regression.

Operationally the system has been working without causing consequences for the windfarm. The "restart" wind speed was increased to 5.5m/s to avoid short-term cycling on/off of the curtailment, so the behaviour of the system is to curtail below 5m/s (when nightly temperatures >11.5°C) but will not restart until the wind speed is >5.5m/s.

Given the performance of the system in minimising fatalities the curtailment system is deemed to be adequate and will continue to be in place for the duration of the project life, with no further bat monitoring proposed.