A Technique for Assessing Bat Activity for Ecological Impact Assessment

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The development of on-shore wind power (in particular) in recent years has generated a vast amount of bat survey data as part of ecological impact assessments in support of planning applications. These data are primarily in the form of numbers of registrations (*i.e.* bat 'passes') recorded from static monitoring points, and are used to give an indication of the species present and their activity within a study area. Survey methodologies and the subsequent interpretation of these data have tended to develop as the industry has grown, driven by an increasing awareness of the potential issues that such development poses to bat species. Activity data are regularly used to determine the conservation value of a study site, and inform on impacts such as habitat loss and, in the context of wind power, the significance of bat turbine collisions/barotrauma. However, despite the progress made in the collection of data, bat activity analysis is often described in simplistic terms with little reference to various parameters or expected activity rates. Furthermore, whilst prescriptive on data collection, current guidance (*e.g.* Hundt 2012) is vague in terms of data analysis and context. This paper presents a technique for assessing bat activity and provides the ability to begin to standardise commonly applied terms such as low or high activity in an objective and comparative manner. It is therefore proposed that the analyses presented within this paper contribute towards the development of an industry-wide standard assessment methodology.

Introduction

The aim of the present work is to produce a reference guide to provide context when assessing site-specific bat activity levels. This utilises data collated by Heritage Environmental Ltd (HEL) to maintain a dataset of bat activity (Bat Activity Database). Whilst onshore wind farm assessments have provided much of the data, information obtained from other developments and non-development sites has also been incorporated within the dataset.

Typical activity levels for different bat species are provided in relation to broad habitat type and for all habitats. By comparing a site's activity with the range of activity rates recorded in the dataset it is possible to begin to provide context for *e.g.* an evaluation of nature conservation importance and an assessment of impacts. In some cases the results could highlight the requirement for further targeted site surveys, or that the site data should be further analysed to note any seasonal, temporal or geographic variations.

It should be noted that HEL accepts no responsibility or liability arising from the use of the analyses presented within this report.

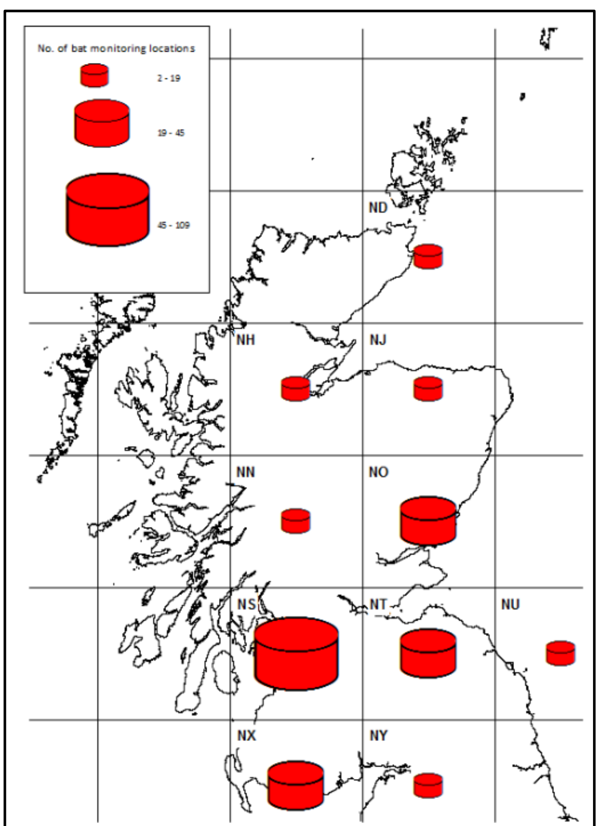
Data Collection

During winter 2013/2014, a request was made across the ecological consultancy industry throughout Scotland regarding the provision of bat activity data from static recording devices. Data were also sourced, where possible, directly from publically available environmental statements and supporting documents.

Initial discussion within the ecological consultancy industry highlighted that it was of critical importance to attempt to be as broad and accepting as possible in terms of designing dataset parameters, in order to gain a suitably large dataset for analysis. Given the differing methods of collection and analysis employed to monitor bat activity, the required survey efforts for data submission were based on minimum guidance standards (Hundt 2012), together with data generated from the most popular method of raw data echolocation analysis.

Around 60 consultancies, companies and individuals were contacted with data requests. In general, and despite a commitment to ensuring data anonymity, the response from the consultancy industry to data requests was cautious. However, a number of consultancies and individuals provided high quality data and useful comment (recognition in conclusions). In total, data from 301 static monitoring points across 10 100 km grid squares were obtained and subsequently interrogated, graphically represented in Figure 1. Of these, 13 points did not record any bat activity and are not included within the analyses.

Figure 1: Bat monitoring locations within 100 km grid squares



Survey Effort

The data are only useful for comparison if collection and analysis are completed using the same general methodology. Therefore, it was requested that data collection met the current minimum standard wind farm survey guidance (Hundt 2012), namely: full night (at least sunset - sunrise) recording for at least 5 consecutive nights per month or per season (spring/summer/autumn) between April and September (inclusive). Provided that the survey effort met the standards stipulated, the following data were requested per monitoring point:

- Detector recording system (all data received was via AnaBat and SM2 recording systems);
- Number of full nights recorded;
- Number of registrations per species for total recording period;
- Habitat type (as defined below);
- Altitude; and,
- 100 km grid square location and county.

Habitat Types and Locational Information

We understand that it is often very difficult for data to be shared - particularly for consultants, such as ourselves, who effectively do not own the data, and when it relates to potentially sensitive projects. Therefore, we were not concerned with site names or specific locations. In order to provide spatial context it was considered that the provision of the historic county subdivision of Scotland level of information and 100 km grid square would be sufficient and was reasonable to request.

Detail on broad habitat type was requested; using the following broad habitat categories:

- Arable;
- Boundary feature habitat (e.g. tree line);
- Broadleaved woodland;
- Clear-fell;
- Coniferous woodland;
- Improved grassland;
- Lacustrine (waterbody);
- Moorland;
- Riparian;
- Scrub;
- Short/ephemeral perennial vegetation ;
- Unimproved grassland; and
- Urban.

Therefore, data queries can be performed at the species and habitat level (*e.g.* soprano pipistrelle and moorland), potentially of use in contexting the bat activity of a study site where sufficient data are present (see below).

Recording Period

It was necessary to standardise time units for deriving activity rates. The time unit used within the analysis is effectively the 24 hour period: the number of full nights' recording was requested. This follows industry guidance for the period in which data activity should be collected (Hundt 2012), being the hours between 30 minutes prior to local sunset to 30 minutes beyond local sunrise. Although many analyses within environmental statements refer to activity in terms of hourly rates or hours of darkness rates, problems immediately present themselves when comparing data gathered from the north of Scotland and the south of Scotland between which there may be a difference of an hour in their respective night length (sunset – sunrise). In order to satisfy the intended outcomes of these analyses (which exclude potential issues of seasonal and temporal variations) and to simplify the data collection process, the 24 hour period or full night unit of time was selected. As bat activity is predominantly nocturnal, rates can be simply described in terms of activity per night.

Analysis Method

Currently, there are 3 commonly used types of activity analysis of recorded bat echolocation:

- registrations/contacts (*e.g.* species presence within a 15 second (s) [max.] file);
- passes (*e.g.* individual passes often described as each sequence of echolocation separated by an agreed length of time prior another sequence); and
- individual calls/pulses.

Comparison between the three methods is currently impossible and would require correction analysis rates to be properly defined (*e.g.* refinement required of *e.g.* Pulses Expected per Unit of Time, Sowler & Middleton 2013). This itself would require analysis at (at least) the habitat level given that bats use echolocation differently as varying habitats (*e.g.* open habitats compared to closed habitats) are traversed and utilised. Therefore, the method chosen for these analyses *i.e.* registrations/contacts, was that which seems to be utilised most often (confirmed through review and discussion).

An industry-wide request was made for data that have been analysed to the level of registrations/contacts of species - *i.e.* presence of species/genus per maximum 15 s file. Multiple passes/calls/pulses of the same species within a (maximum) 15 s file counts as a single registration - two species within the same 15 s file are counted as two registrations.

Zero Data Analysis

A no presence (*i.e.* a point with 0 particular species registrations/night) score does not inform us beyond, 'no bats of a certain species have been recorded at this site'. In order to assess relative activity levels between sites, 0 scores would only detract from such comparisons by depressing activity rates. Zero scores have therefore been excluded.

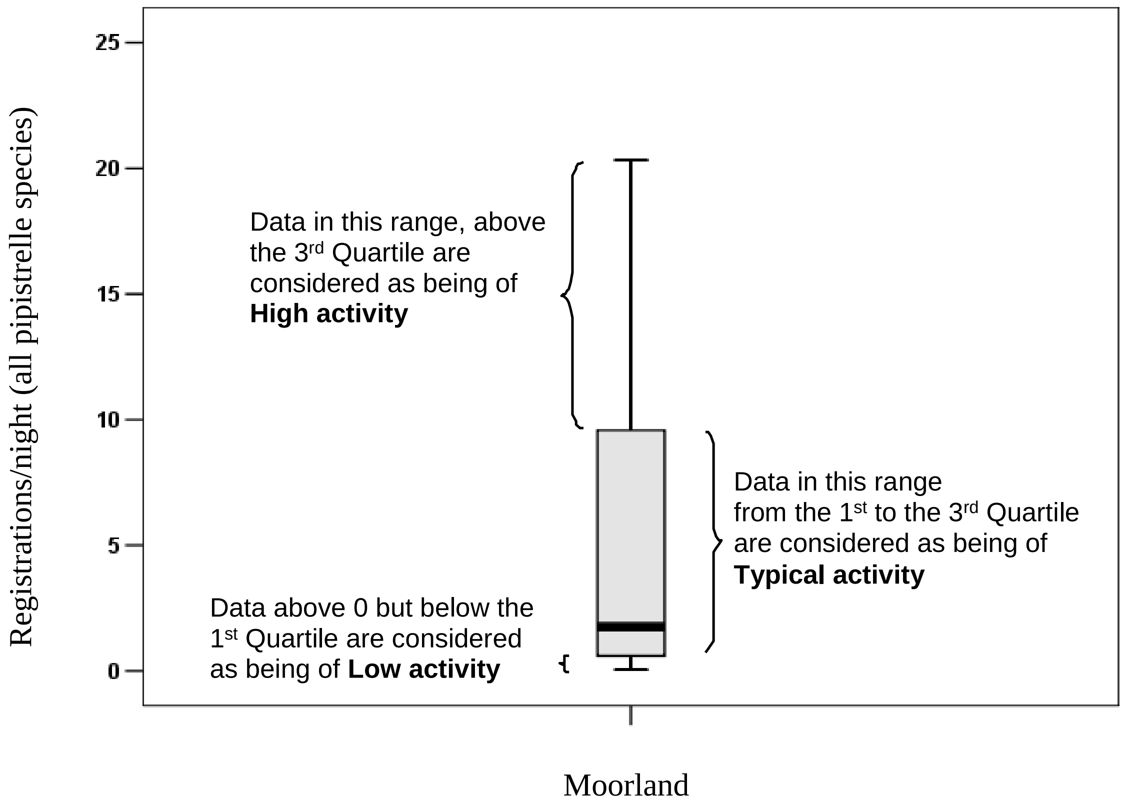
Quantifying Activity

In quantifying activity levels, Hundt (2012) suggests simply calculating a bat activity index as a measure of presence (passes, registrations, etc.) per unit of time and using this to quantify activity and compare distribution of bats, for example in different broad habitat types or in different areas within a site. In the literal sense, this would be interpreted (perhaps particularly by consultants) as within a development (*e.g.* wind farm) study area. This site-based approach does not involve any wider comparative analysis of activity levels, and therefore is of limited value in relation to contexting the nature conservation value of the study area, and assessing the significance of impacts.

Activity levels are represented by a range of values, with the presumption being that the higher the value the more important the site is functionally from a bat's perspective. From these levels, activity thresholds can be derived by a variety of methods. The interquartile range approach is adopted here as it provides a simple method that is considered appropriate, and provides three useful bandings. Activity thresholds have therefore been quantified according to the following (represented within Figure 2):

- **High activity level**: a registration rate that is higher than typically recorded for the parameters concerned: above the 3rd quartile;
- **Typical activity level**: a registration rate that is typically recorded for the parameters concerned: between the 1st and the 3rd quartile; and
- **Low activity level**: a registration rate that is lower than typically recorded for the parameters concerned: below the 1st quartile.

Figure 2. Schematic representation of bat data – in this case the level of activity associated with total pipistrelle registrations per night on moorland.



Most simply, the interquartile ranges have been derived per species against all records (*i.e.* all habitat types) of sufficient sample size. This is shown in Table 1. Given that differences in habitat class (a major component in the distribution of bat numbers, activity and species) have been found (ANOVA, $F = 1.826$, $p = 0.0391$), data have also been analysed according to species and habitat type: also presented within Table 1. Thus the activity rates of a particular study site can be compared with those returned from the dataset (at the basic levels of per species per all habitat and per species per defined habitat).

In order to place a given rate within an activity level (*i.e.* high, typical or low activity) there needs to be a certain number of data points available; at present we have given a limit of 12 points ($n = 12$) such that a split of 3:6:3 can be used as the comparative. Clearly the more data points per category the better, but in order to make the analyses worthwhile it is considered 12 represents an acceptable minimum cut off point. Table 2 indicates which species and habitat selections presently meet the criteria for analysis.

Limitations and Expected Variance

From the outset it was recognised that issues of ownership and anonymity would cause problems in the release of data; this influenced the selection of criteria in order to alleviate any concerns.

There are some obvious temporal and environmental parameters that would be useful to include within the analyses: *e.g.* time of night, monthly/seasonal rates, air temperature and wind speed. There is also no provision for recording proximity of nearest known roost/s (indeed this would likely be unknown in many sampling sites) and their seasonal use. Doubtless there are many other factors that play a role in determining site specific activity.

It should be noted that detectability between genera is very variable and that therefore it is not possible to compare registration rates between genera. Indices of bat activity do not relate directly to numbers of bats and are useful only in like-for-like comparison analysis. Within these data analyses, activity is described in terms of 'that typically encountered' for the species or genera concerned. It should also be noted that the presence of (the relatively common and widespread) brown long-eared bat is likely to have been under-recorded within data supplied due to recognised problems of detectability.

An additional problem has been encountered during comparison studies when testing the returned activity indices. There are a high proportion of records within the dataset that have been identified to genus level only for *Myotis* and *Nyctalus* (*i.e.* not identified to species level). Thus, (likely) discrepancies currently occur when comparing, for example, a site's Leisler's bat rates against the derived activity rates (quartiles) for Leisler's bat and total *Nyctalus*. It is anticipated that such problems will slowly resolve as the dataset grows. As it is not possible to always be confident in identifying to species level, perhaps it is better to consider comparing at the genus level in the first instance. Table 2 provides the numbers of positive sample points where a species has been identified within a habitat category and should be referred to during consideration of comparative analysis.

Data Testing

Prior to undertaking parameter analysis, data were subject to significance testing in order to determine which data could be included. Data were collected by different methods (namely SM2 and AnaBat) and not all data met the requested seasonal parameters. Therefore, the following tests were performed as to determine to what level data could be used:

- Seasonality significance test; and
- Detector significance test.

Seasonality Significance Test
Data were provided that did not meet criteria for example in terms of their temporal or seasonal spread and/or in terms of analysis. A first step then was to determine whether the 'incomplete' data set could be used together/alongside the complete data. For this, we analysed the two data sets (incomplete vs. complete spring, summer and autumn [SSA] data) to detect if differences were present, for example in the overall level of bats per night recorded.

A total of 144 monitoring points were collated where data had been recorded according to the specified seasonality parameters (*i.e.* at least 5 nights recording per SSA); a further 144 monitoring points did not meet these criteria. An analysis of variance (ANOVA) was carried out on the data (natural log transformed to produce a normally-distributed data set for the purposes of this analysis). No statistically significant differences were found between the 2 groups (SSA and incomplete data; ANOVA, $F = 0.000$, $p = 0.993$). This would mean that the data recorded at a reduced level of survey do not differ from those recorded at the best practice level across the seasons, allowing the data to be merged into a single dataset for further query.

Detector Significance Test
Data collected from both AnaBat and SM2 recording systems have been accepted since they appear to be the two most commonly deployed remote bat recording systems used in Scotland (confirmed through subsequent discussion with consultants post data request). It is recognised that there is variance regarding echolocation detection between the systems (*e.g.* Ryan *et al.* 2011). SM2 recording units have been measured to record echolocation over greater distances than AnaBat units (*e.g.* Adams 2013) and are also less affected by placement angle when used with their omni-directional microphone (AnaBat uses a unidirectional microphone). In addition to the recognised variance in recording units, different microphone types possess varying sensitivity: an unavoidable reality (Agranat 2014).

In drafting the methodology for this study, a decision was made to be as encompassing as possible in data collection. The aim here is to use as wide a dataset as possible, as it would not be achievable to collect the same amount of data from such a wide range of studies if all detector systems had to employ identical, calibrated equipment. However, the data samples do allow for basic significance testing between the two commonly used recording systems.

Of the 288 points, 191 monitoring points were collated where data had been recorded using AnaBat, with 97 monitoring points using SM2. ANOVA was carried out on the full data set (*i.e.* SSA and incomplete data taken together since we had determined no statistical difference between these; transformed data were used to allow the use of parametric statistics). No statistically significant differences were found between the 2 groups – ANOVA, $F = 0.615$, $p = 0.433$). Therefore, the full data set, irrespective as to whether the data were obtained from AnaBat or SM2, or whether or not there was a full season of data recorded, represents a source that can be interrogated further. Please note that we do not advocate the collection of less than a full season's activity data!

Results

The results of analysis are provided within Table 1. Blank cells indicate that number of sample points does not currently meet criteria for analysis (as does absence of species, notably noctule *Nyctalus noctula* and Nathusius' pipistrelle *Pipistrellus nathusii*). Table 1 shows the 'Typical activity' levels (registrations/night) for species and habitat. All habitats (last column) simply expresses the average of the activity level per habitat class, removing the skew in the dataset due to a survey bias towards wind farm sites (most often found within coniferous woodland and moorland habitats in Scotland).

Given that the three activity levels have been derived using the median rather than a mean value, we would suggest that it is not appropriate to further define an activity rate within any level.

Table 1. Typical activity levels (registrations/night) according to species and habitat class.

Species	Boundary	Broadleaved woodland	Coniferous woodland	Improved grassland	Moorland	Riparian	All habitats
Common pipistrelle	**0.77-12.71**	**3.27 – 107.70**	**1.28 – 21.39**	**3.20 – 8.29**	**0.46 – 3.81**	**2.04 – 12.24**	**1.84 – 27.69**
Soprano pipistrelle	**1.25 – 22.47**	**6.90 – 46.35**	**1.61 – 28.39**	**2.80 – 6.86**	**0.25 – 6.03**	**1.85 – 21.61**	**2.44 – 21.95**
Total *Pipistrellus* (including unidentified	**1.90 – 47.58**	**23.81 – 122.20**	**2.78 – 52.90**	**7.27 – 24.81**	**0.60 – 9.38**	**5.09 – 45.14**	**6.91 – 50.33**
Natterer's bat	~	~	**0.07 – 0.26**	~	~	~	**0.07 – 0.26**
Daubenton's bat	~	~	**0.11 – 1.64**	~	**0.08 – 0.37**	~	**0.10 – 1.01**
Total *Myotis* (including unidentified	**0.16 – 0.74**	~	**0.16 – 1.73**	~	**0.09 – 0.60**	**0.14 – 1.19**	**0.14 – 1.07**
Leisler's bat	~	~	**0.13 – 0.53**	~	~	~	**0.13 – 0.53**
Total *Nyctalus* (including unidentified)	**0.07 – 0.33**	~	**0.08 – 1.27**	~	**0.04 – 0.54**	~	**0.06 – 0.71**
Brown long-eared bat	~	~	**0.04 – 0.21**	~	~	~	**0.04 – 0.21**

The number of data points according to habitat class and species level are shown below in Table 2. Those for which 12 or more points are available (in bold) are suggested to be of sufficient size to allow further interrogation on habitat type.

Table 2. Data sample sizes

Species	Arable	Boundary	Broadleaved woodland	Clear-fell	Coniferous woodland	Improved pasture	Lacustrine	Moorland	Riparian	Scrub	Short/ephemeral perennial vegetation	Unimproved pasture	Urban
Common pipistrelle	6	**26**	**13**	4	**95**	**13**	8	**65**	**22**	3	6	4	1
Soprano pipistrelle	6	**24**	**13**	4	**98**	**13**	8	**58**	**23**	2	5	4	1
Nathusius' pipistrelle	~	3	3	~	4	3	~	5	2	~	~	1	~
Total *Pipistrellus* (including unidentified)	7	**26**	**13**	4	**100**	**13**	8	**70**	**24**	3	6	4	7
Natterer's bat	1	3	3	~	**18**	4	1	3	~	~	~	~	~
Daubenton's bat	2	5	3	4	**42**	5	4	**30**	9	~	~	~	~
Whiskered bat	~	~	1	~	~	~	~	~	~	~	~	~	~
Total *Myotis* (including unidentified)	5	**23**	9	4	**84**	11	8	**49**	**19**	1	3	4	1
Leisler's bat	1	4	1	4	**35**	4	2	6	6	~	~	1	~
Noctule	~	4	2	~	7	5	~	6	0	~	~	~	~
Total *Nyctalus* (including unidentified)	3	**12**	3	4	**53**	9	4	**13**	11	1	5	2	~
Brown long-eared bat	1	4	1	~	**27**	4	2	9	5	~	~	1	~

Case Study

A bat impact assessment is being undertaken on a moorland site in the Scottish Borders in relation to a proposed wind farm development. A level of soprano pipistrelle activity has been recorded at an average rate of 12.1 registrations per night. Pipistrelle species are considered as at Medium to High risk due to wind farm developments (Mitchell-Jones & Carlin 2014) and as such are a relevant group for assessment.

Until now it has been difficult to put these data into a relevant context; exactly how does a rate of 12.1 passes per night data relate to other areas of similar habitat in terms of bat (pipistrelle) passes and activity levels?

Table 3: Soprano pipistrelle/moorland activity rates (registrations per night)

Species	**Habitat**	**Low activity**	**Typical Activity**	**High Activity**
Soprano pipistrelle	Moorland	0.01 – 0.24	0.25 - 6.03	> 6.03
Soprano pipistrelle	All habitats	0.01 – 2.43	2.44 – 21.95	>21.95

Table 3 shows that for all habitats combined, the rate of 12.1 registrations per night equates to a Typical Activity level. However, for moorland habitat, 12.1 registrations per night equates to a High Activity level.

In addition to being able to better describe the activity of pipistrelle within our study site, further data queries have naturally been exposed – *e.g.* although of a typical rate against all habitat, why is the rate higher than may be expected for moorland? This may flag up the requirement for further survey: perhaps the activity is not typical of the local area; perhaps activity is indicative of the presence of a nearby roost, seasonally biased or related to the presence of prey (*e.g.* insect hatches). In relation to turbine collision/barotrauma risk the High Activity level for moorland may require that at height surveys be undertaken to assess the level of impact significance. Had the activity rates been assignable to the Low Activity level (and there were no seasonal peaks of activity) it may seem reasonable to assess the collision/barotrauma risk as non-significant.

Future Collaboration

HEL have agreed to support and work with University of Exeter Biosciences department in taking the bat activity project forward. The University of Exeter have been working separately on producing bat activity reference ranges and are investing in the development of a website which will have to capacity to generate an instant output (*i.e.* percentile level and if this is classified as 'high', 'moderate' or 'low' activity' stratified by a series of geographical, environmental and location variables).

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