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# Large-scale citizen science improves assessment of risk posed by wind farms to bats in southern Scotland

Stuart E. Newson[a,*], Hazel E. Evans[a], Simon Gillings[a], David Jarrett[a], Robert Raynor[b], Mark W. Wilson[a]

[a] British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU, UK
[b] Scottish Natural Heritage, Great Glen House, Inverness IV3 8NW, UK

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ABSTRACT

In order to ensure that the placement of future wind energy developments does not conflict with important areas for bats, surveys and analyses are required to deliver a robust understanding of large-scale patterns in species' distributions and abundance. We demonstrate that extensive presence-absence survey data can be collected for bats across a large (> 20,000 km$^2$) region of southern Scotland using volunteers supplemented with additional fieldworker effort in remote areas. We advocate a survey design that allows data to be collected for all bat species, but provide more focused analyses on three species (Leisler's bat, noctule and Nathusius' pipistrelle) that are currently considered to be at highest risk from wind turbines. We estimate that between 16% and 24% of the regional populations of these three high risk species overlap existing and approved wind farms, with 50% of this overlap concentrated at just 10% of wind farms. This emphasises the importance of new wind farm placement to minimise impact on these species. We have stratified the region according to the potential impact on bats of future wind farm development, highlighting those areas in the top 1%, 5% and 10% of risk. We conclude that there is a need for higher quality data of this type in order to inform spatial models of bat distribution and activity. As a minimum standard, researchers working on bats should prioritise the collection and use of presence-absence data with consideration of the underlying survey design and representativeness of the data collected. This can be achieved most cost-effectively by working with the public to develop large-scale acoustic monitoring schemes.

## 1. Introduction

Worldwide efforts to develop sustainable methods of energy production have led to an increase in the use of renewable sources, with particular emphasis on wind energy. Despite clear environmental benefits associated with this type of technology, many studies have identified bat fatalities at wind farms, which raise concerns about the effects of wind turbines on bats (e.g. Rodrigues et al., 2015; Lintott et al., 2016). To minimise the impact of future wind farm development on bats, perhaps the most straightforward means is to identify key areas for bats. This requires surveys and analyses that are able to provide a robust understanding of large-scale patterns in species' distributions and abundance (Pereira and Cooper, 2006; Jones, 2011).

Provision of the necessary data is particularly challenging for bats, because most species are nocturnal, wide ranging and difficult to identify. As a consequence, the majority of published spatial modelling studies on bats have used presence-only data (i.e. where there is no direct information collected about either real absence or non-detection), collected through unstructured opportunistic sampling (reviewed in Razgour et al., 2016). This is despite there being considerable literature on the value of random or representative sampling, and of prioritising the collection and analysis of presence-absence data (strictly detection/non-detection data) (e.g. Brotons et al., 2004; Ward et al., 2009). With developments in passive bat detectors, software to aid the analysis of sound files and improving knowledge of species identification (Barataud, 2015), it is now possible to conduct large-scale representative acoustic assessment of bat species' distributions using presence-absence data and information on activity as a measure of abundance (e.g. Newson et al., 2015).

Typically, bat data are largely collected by skilled specialists, with the spatial and temporal extent of these data often being limited by the time and expense required to collect them (Martin et al., 2012). However, there is now an opportunity to engage with volunteers to encourage random or representative sampling through the deployment of

* Corresponding author.
*E-mail address:* stuart.newson@bto.org (S.E. Newson).

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autonomous bat detectors. Collection of presence-absence and activity data for bats over large spatial scales, and robust analyses of these data, are urgently needed to guide decision making. Citizen science is increasingly used and recognised as a valuable tool for biodiversity monitoring and scientific research (Dickinson et al., 2010; Danielsen et al., 2014). In the case of acoustic monitoring for bats, the use of autonomous recording devices and standardised protocols for deploying detectors has proven potential to provide data that is comparable in quality to that collected by bat specialists, but at a fraction of the cost (Newson et al., 2015). Working with volunteers in this way has the added benefit of increasing public interest and awareness of the value of biodiversity (Danielsen et al., 2011; Hochachka et al., 2012; Miller-Rushing et al., 2012).

In this study, we capitalise on the enthusiasm of volunteers to participate in biodiversity monitoring to collect systematic bat distribution and activity data throughout southern Scotland, an area which has one of the highest densities of wind farms in Britain (The Wind Power, 2015), and for which there is a particular paucity of relevant information on bats to guide decision making. Until we have a better evidence base of understanding of wind farm impacts on bats, it is important that studies looking at the impact of wind farms on bats do not restrict data collection to species currently believed to be at 'high risk'. We advocate collecting data on all species of bats in the region, but carry out more focused analyses on three bat species (Leisler's bat *Nyctalus leisleri*, noctule *Nyctalus noctula* and Nathusius' pipistrelle *Pipistrellus nathusii*) that are currently considered to be at highest risk from wind turbine development in southern Scotland. We examine the likelihood of the three species being present at wind farms in the region, and identify areas where the risk of wind turbine construction would be greatest. All three of these species have previously been reported in pre-construction surveys at existing and proposed wind farm sites in the region (source: Scottish Natural Heritage). In some of these surveys, patterns of activity suggested regular foraging in the survey area, or the presence of a nearby roost. Current understanding of the status of all three of these species of bats in Scotland is poor. For all bat species except Nathusius' pipistrelle for which no estimate exists, current population estimates are 20 years old and based on expert opinion (Harris et al., 1995), and suggest that Scottish populations may be limited to a few hundred individuals of each species. More recent information suggests that the population sizes for these species are larger than this (Scottish Leisler's Bat Project unpubl. Data), but there is a persistent belief that these species are rare and occupy restricted ranges in Scotland. There is no published Scottish population estimate for Nathusius' pipistrelle, although it has been suggested that the total British population may be around 4000 individuals (Battersby, 2005).

Given the rarity (or, at least, the perceived rarity) of these species in southern Scotland, the fact that the two *Nyctalus* species are believed to be at the northern edge of their British and western European ranges, and their vulnerability to wind turbines based on collision mortality data, there is an urgent need for better and more comprehensive information on their respective ranges and activity. These data are needed to improve assessments of the likely impacts of existing and future wind farm developments, and to inform recommendations about further data collection and analysis aimed at improving our understanding of bat populations in relation to wind farm construction.

## 2. Methods

### 2.1. Southern Scotland Bat Survey protocol

The project focused on a survey area of 21,033 km$^2$, roughly comprising the southern third of Scotland (Fig. 1). Apart from planning applications for wind turbines, there has been little in the way of extensive or systematic bat recording in this area, although local studies and ad hoc recording have recorded 10 species to date (Table 1). The mixture of landscapes, and inclusion of areas with both very high and very low human population densities, make it a good area in which to consider and test approaches to some likely challenges of large-scale volunteer-based bat recording.

The Southern Scotland Bat Survey (www.batsurvey.org) ran from the beginning of May until the beginning of October 2016. Collaborating with several organisations and local libraries, we set up 16 "Bat Monitoring Centres" at locations already open to and used by the public, from which anyone could borrow a passive real-time bat detector for a few days. The detectors were Wildlife Acoustics SM2Bat + detectors, which record in full-spectrum at 384 kHz (Waters and Barlow, 2013) and automatically trigger by calls of passing bats. A high pass filter of 4 kHz was used to define the lower bound of the frequencies of interest for the triggering mechanism. Recording was set to continue until no trigger was detected for a 2.0 s period. Two paid fieldworkers deployed detectors in areas and habitats where volunteer uptake during the season was low. This was done by monitoring volunteer uptake during the season, and using an adaptive approach to deploy paid fieldworker effort in a strategic gap-filling manner.

Detectors were typically deployed at sampling locations at c.6 pm and left to record until the following morning following guidance for microphone placement in Newson et al. (2015). Between one and three nights of recordings were collected in each sampled 1-km square with locations for different nights of recordings being separated by at least 200 m. Volunteers were encouraged to preferentially select one or more 1-km square to survey from 1000 'priority' squares. These squares were randomly selected, prior to the start of the survey season, from all 1-km squares in the survey area that were not associated with human habitation, as defined as not containing the Centre for Ecology and Hydrology (CEH) 2007 landcover category 'built up areas and gardens' (Morton et al., 2011). We adopted this approach following a similar, smaller project in Norfolk (Newson et al., 2015) which found that 1-km squares chosen by volunteers tended to be biased towards areas with high human population (i.e. close to where volunteers live). Where selecting a random priority square was not feasible, volunteers were given the opportunity to select an alternative square of their choice for surveying, on the understanding that we would need to test for and potentially correct for bias.

### 2.2. Semi-automated acoustic identification of bats

Passive real-time detectors are triggered when they detect sound within a certain frequency range. Monitoring on this scale can generate a very large volume of recordings, efficient processing of which is greatly aided by a semi-automated approach for assigning recordings to species. In this study we made use of an acoustic classifier *TADARIDA* (a Toolbox for Animal Detection in Acoustic Recordings Integrating Discriminant Analysis; Bas, 2016; Bas et al., 2017). All recordings from the Southern Scotland Bat Survey were passed through the *TADARIDA* random forest classifier (Step 1). This entailed extraction of 150 measures of call characteristics from each recording (Bas et al., 2017), and a comparison of these against measurements taken from an extensive reference library of manually identified ultrasound recordings.

The classifier allows up to four different "identities" to be assigned to a single recording, according to probability distributions between detected and classified sound events. From these, species identities are assigned by the classifier, along with an estimated probability of correct classification (as compared with the underlying training database) on a scale of 0–1. For common *Pipistrellus pipistrellus* and soprano pipistrelle *Pipistrellus pygmaeus*, which accounted for > 95% of all bat recordings made during the survey, the call shape (similar to a hockey-stick) and frequencies of common and soprano pipistrelle are sufficiently characteristic to allow reliable classification of these species by the classifier. For these species, *TADARIDA* identifications for which the estimated probability of correct classification was high ($\geq$ 0.8), were taken as being accurate.

Manual checking (Step 2) of spectrograms using software SonoBat