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A novel citizen science approach for large-scale standardised monitoring of bat activity and distribution, evaluated in eastern England

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ABSTRACT

In many countries, bats have high conservation prioritisation owing to their trophic position, habitat associations and threat level, and many have dedicated management plans. However, poor knowledge of species' ecology, identification issues and surveying challenges mean that large-scale monitoring to produce required distribution and abundance information is less developed than for some other taxa. Static detectors deployed to record bats throughout whole nights have been recommended for standardised acoustic monitoring but to date their cost has prohibited wide uptake. Here we describe an extensive survey approach in which members of the public borrowed detectors to participate in a large-scale monitoring and mapping project. Covering a 15% sample of the study area over two years, the survey generated over 600,000 bat recordings. We describe a semi-automated step-wise method for processing this large volume of recordings to assign identity to species or genus level with low error rates. Twelve species were recorded during the survey, ranging from the near ubiquitous Common Pipistrelle *Pipistrellus pipistrellus* to the locally scarce Leisler's bat *Nyctalus leisleri*. We show pronounced patterns of seasonality consistent with post-breeding dispersal and new information on nocturnal activity patterns. Using regression trees we generate new maps of standardised variation in activity which is likely to reflect underlying spatial variation in relative abundance. These reveal hitherto unknown patterns for species of superficially similar status. We conclude that with logistical support and centralised automated species identification it is now possible for the public to contribute to acoustic bat monitoring at an unprecedented scale.

1. Introduction

Biodiversity is facing an unprecedented decline whilst the pressure on the earth's ecosystems continues to grow (Butchart et al., 2010). Recognising the status of biodiversity and its benefit to human well-being, the world's governments committed in 2010 to take effective and urgent action to halt biodiversity loss through the Convention on Biological Diversity's targets (de Heer et al., 2005; Pereira et al., 2010). These targets require monitoring to assess progress towards specific goals. Such large-scale biodiversity assessment calls for methods which are able to provide an understanding of large-scale patterns in species' distributions, abundances and changes over time (Pereira and Cooper, 2006; Jones, 2011). This relies on surveys to collect data that are representative at a regional to national scale, and robust analysis that is able to provide an informed understanding of species' populations (Magurran and Dornelas, 2010).

As a group, bats (Chiroptera) are challenging to monitor because most are nocturnal, wide-ranging and can be difficult to identify. Historically the monitoring of bats in temperate regions has focused on intensive (site-based) visual counts at volunteer-selected winter or summer roosts (Battersby, 2010; Haysom et al., 2014) or capture surveys (Hayes et al., 2009). There is considerable value in these approaches, but it is difficult to confidently infer from these what is happening at a wider population level. For conservation purposes, it is essential that small-scale or local processes be distinguished from processes that may affect populations over larger scales. Therefore, the ability to also assess processes operating at a broader population level is necessary, for which an extensive regional, approach is required.

With developments in passive bat detectors and software for semi-automating the analysis of sound files, there is the potential to provide large-scale representative acoustic monitoring of bat species distribution and activity as a measure of relative abundance (Lintott et al., 2014). Stahlschmidt and Brühl (2012) recently highlighted concerns mirrored in the wider literature (Hayes, 2000; Sherwin et al., 2000; Gannon et al., 2003) that current methodology for monitoring bat populations using acoustic methods often fails to address temporal and spatial variation in bat activity. We would go further to say that more generally, robust information on species occurrence and activity are lacking, with researchers relying on presence-only data, where there is no direct information on absences (strictly absence or non-detection), and which is often obtained through unstructured opportunistic sampling. As a consequence, most recent spatial modelling has used presence-only data (but see Rodhouse et al., 2012; Meyer, 2014).

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The usual argument for using presence-only data has been that large scale presence/absence data and abundance data sets are unavailable or unreliable, but little work has looked at designing work to improve the quality or availability of these data. Clearly a standardised bat survey method using a suitable detector system recording bat activity as a measure of relative abundance and presence/absence is needed. This is particularly important because significant population declines of species of high conservation concern may occur before any reduction in range is observed (Gaston, 2003), where measures of abundance are regarded as the most informative variable for monitoring change in populations and essential for underpinning local and national decision making, targeting of conservation action and providing evidence for biodiversity reporting.

Comparing two widely used methods to survey bat activity, walked line transects and static detectors, Stahlschmidt and Brühl (2012) demonstrated that the use of automatically triggered (often known as passive) real-time bat detectors placed at randomly selected points to record all night, is most likely to produce unbiased standardised data on the relative activity of bats. Whilst this might be ideal, in practice the cost of real-time bat detectors required for this purpose remains high, so this technology and approach has largely been restricted to localised intensive use by environmental consultants or university research groups. In contrast, well developed volunteer-based national or regional bat monitoring programmes typically use simple, tuneable heterodyne detectors that focus on detecting the presence of a small number of relatively easily identifiable species, with the survey methods designed to be as inclusive as possible and using affordable bat detectors to maximise participation and geographical coverage (e.g. the United Kingdom's National Bat Monitoring Programme, NBMP; Barlow et al., 2015). Few species are easily monitored through these methods due to the difficulty in confidently distinguishing the calls of many species, and it is often difficult to produce a standardised measure of bat activity for the suite of species that can be monitored (Walters et al., 2013).

One approach for getting better species coverage and higher quality acoustic data has been the iBats program (www.ibats.org.uk) (Jones et al., 2013), where volunteers across a number of European countries drive along roads at night, using more expensive time-expansion broad-band detectors to record bats. Similar projects are being carried out in other countries (e.g. Ireland, Roche et al., 2011). In doing so, this approach is able to make use of a small number of volunteers and limited equipment to potentially obtain a large volume of data to inform on species distributions. Because of the simplicity of the survey design, the approach is increasing our knowledge of large-scale distribution patterns across a large geographic area, and by making repeat visits to the same transects at the same time of night, it has the potential to provide a robust measure of change in relative abundance on surveyed transects. Assuming that driven transects are faster than a bat can fly, it can also be assumed that recordings relate to different individuals. Its limitations are that it is difficult to compare bat activity directly within and between transects because activity is likely to vary with time of night (Hayes, 2000). In addition, conclusions from a monitoring project based on the road network can only be made in relation to roadside habitats, which may not be representative of wider bat populations (Roche et al., 2011). Similar criticism has been made of the North American Breeding Bird Survey, where restricting bird surveys to roadsides has been shown to limit the representativeness of the data, resulting in skewed abundance, distribution and community composition data (Thogmartin et al., 2006; Betts et al., 2007; Niemuth et al., 2007; McCarthy et al., 2012), reducing the reliability of associated population and trend estimates and distribution models that are developed to guide conservation-related programmes (Bart et al., 1995, 2004; Francis et al., 2005; Sauer et al., 2005).

Clearly for the large-scale monitoring of bat activity there is a need for a standardised survey design. The objectives of this study were to trial the recording of bat activity using passive real-time detectors, to gauge the willingness of members of the public to engage in bat monitoring on a large scale, and to determine the suitability of automated identification routines for processing large volume of citizen-collected recordings. We describe this approach and carry out a critical evaluation of the different stages of the approach, from field deployment to bat identification, and provide provisional results indicating the insights such a scheme can provide for understanding bat status and ecology, and potential for informing conservation planning.

2. Methods

2.1. Norfolk and the Norfolk Bat Survey protocol

Norfolk is a coastal county of 5371 km^2 in eastern England (Fig. 1). It is dominated by arable farmland with scattered woodlands and towns, plus significant wetland-dominated landscapes of international importance (e.g. the Norfolk Broads) and Breckland, an area of sandy heathland and forest (Dymond, 1990). It has not previously been the subject of large-scale bat monitoring, but local studies and ad hoc recordings have to date recorded 12 species (Table 1) including a cryptic species pair where acoustic identification is particularly difficult (Whiskered bat *Myotis mystacinus* and Brandt's bat *Myotis brandtii*). The mixture of landscapes, distribution of observers and local NGOs (see below) made it a good choice for trialling large-scale volunteer-based bat recording.

The Norfolk Bat Survey (www.batsurvey.org) was set up in spring 2013 to enable members of the public to have access to passive real-time bat detectors which they could place in a location of their choice within Norfolk to automatically trigger and record the calls to a memory card every time a bat passes throughout a night. We collaborated with several organisations and local libraries across the county to set up 21 "Bat Monitoring Centres" at existing centres used by the public from which anyone could borrow the equipment for a few days (Wildlife Acoustic SM2Bat+ detector recording in full-spectrum at 384 kHz, see Waters and Barlow, 2013). Microphones were mounted on 3-m poles to avoid ground noise and reduce recordings of reflected calls, and a low pass filter of 8 kHz used to reduce the chance of non-bat noise from triggering the detector. Recording was set to continue until no trigger was detected for a 2.0 second period. Guidance was given to avoid surveying bats in persistent heavy rain, strong wind or if the nightly temperature was predicted to fall well below 7 °C, and on the placement of microphones which should be deployed at least 1.5 m in any direction from vegetation, water or other obstructions. Intensive field trials were carried out prior to the survey season to inform a decision on the survey effort required to provide a reliable representation of species present within a 1-km square (Newson et al., 2014). Based on this, a compromise of three complete nights of recording at three different points located at least 200 m apart within each 1-km square was taken, accepting that species at low density or with a low detection probability may be missed over three nights of recording (see also Skalak et al., 2012). At the end of the three nights of recording, the memory card was returned to the British Trust for Ornithology (BTO) for analyses, along with a completed recording form giving the dates and grid references at which the detector was used. In return for collecting data, participants were sent a summary of the bat species they recorded within a few days of taking part. Using this method, members of the public were given an opportunity to participate in bat surveys and take advantage of bat recording technology that would not normally be available to them. The survey period ran from mid-April to the end of September to cover the core period of bat activity in the UK, and to maximise use of the equipment during the year. Ideally, 1-km squares would be selected and allocated at random to volunteers to ensure representative coverage across the county. In this project we allowed for a free choice of 1-km squares to encourage participant uptake, but on the understanding that we would need to test for and potentially correct for likely bias towards sampling in or near areas of human habitation. Here we make use of data from the first two years of the survey.