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Research Paper

Predicting the likely impact of urbanisation on bat populations using citizen science data, a case study for Norfolk, UK

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HIGHLIGHTS

- Housing development is predicted to decrease the occurrence and activity of bats.
- Preferentially developing least-preferred habitats reduces impacts.
- Sensitivity maps of occurrence weighted by avoidance metrics can aid urban planning.
- Inter-specific variation in habitat preferences preclude mitigation for all species.
- Citizen science bat surveys provide unique access and insights in urban areas.

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ABSTRACT

Urban land cover is the fastest growing land-use form globally and there is concern that urbanisation will negatively impact native biodiversity. Bats are ecologically diverse predators and their responses to urban development may provide insights into wider biodiversity responses to urbanisation. Developments in bat detection methods mean it is now possible for citizen scientists to collect detailed bat distribution data. The geographical and habitat coverage of such data make them ideal for addressing urban planning issues. In this paper we quantify the impact of planned housing on bat populations and evaluate possible mitigation measures. We combined data on 12 bat species collected through a large citizen science project in Norfolk, UK, with spatially explicit housing plans for the next decade and tested the impact of mitigation planning scenarios operating at different spatial scales. The planned housing was predicted to decrease occurrence or activity for all 12 bat species. Locally, these decreases could be substantial, leading to a reduction in the likelihood of occurrence from 40% to 1%. However, at a county-scale the proposed level of housing is equivalent to less than a 2% decrease in total occurrence and abundance across all species. The negative effect of planned housing could be reduced by 46% on average by preferentially building on less preferred habitats and in areas with low populations of urban-sensitive bat species. This paper demonstrates an easily transferable method for determining rich habitats where new developments should be avoided and for investigating the potential of mitigation strategies.

1. Introduction

The human population is increasing exponentially (United Nations, 2015). Consequently, urban areas are growing, and with a predicted increase in global urban land cover of between 430,000 km^2 and 12,568,000 km^2 by 2030 (Seto, Fragkias, Guneralp, & Reilly, 2011), it makes this the fastest growing land-use form globally (Hansen et al., 2005; Lin & Fuller, 2013; Seto et al., 2011). Urban growth is considered to be one of the most irreversible human impacts on the global biosphere and will have severe negative effects on biodiversity (Seto et al., 2011). The average number of threatened species per nation is expected to increase by 14% by 2050 due to changes in human population growth and the associated effects of urbanisation (Mckee, Sciulli, Fooce, & Waite, 2004). Urban growth may negatively impact species through a number of routes: loss and fragmentation of natural habitat (Mckinney, 2002),

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increased number of roads (Fahrig & Rytwinski, 2009), increased pollution (light: Longcore & Rich, 2004, noise: Patricelli & Blickley, 2006, chemicals: Bradley & Altizer, 2007), an increased density of domestic predators (Bonnington, Gaston, & Evans, 2013), and through direct human actions (Russo & Ancillotto, 2015; Young et al., 2007). Knowing this, it is important to assess the effects that proposed urban expansion is likely to have on native biodiversity (Lin & Fuller, 2013) and to look at ways of mitigating against such impacts as far as possible. This could be done by ensuring that new building developments avoid hotspots for rare or localised species, or by adapting plans to integrate wildlife-friendly areas or corridors, where it can be demonstrated that these approaches work (Ahern, 2013; Berthinussen, Richardson, & Altringham, 2014).

Bats are a diverse group of over 1300 species with different habitat preferences and requirements (Nowak, 1994). The IUCN Red List classifies 253 bat species as threatened or near threatened, which includes two species present in the UK (IUCN, 2015). Due to bats' diversity, widespread distribution, high trophic level, importance as ecosystem service providers and relatively stable taxonomy, there has recently been exploration of the potential for using bats as bio-indicators to assess anthropogenically induced changes in environmental quality over time (Jones, Jacobs, Kunz, Willig, & Racey, 2009; Newson et al., 2009; Russo & Jones, 2015). Bats, like many other taxa, have generally responded negatively to urbanisation (Avila-Flores & Fenton, 2005; Caryl, Lumsden, Van Der Ree, & Wintle, 2016; Coleman & Barclay, 2012; Duchamp, Sparks, & Whitaker, 2004; Gaisler, Zukal, Rehak, & Homolka, 1998; Hale, Fairbrass, Matthews, & Sadler, 2012; Lintott, Bunnefeld, & Park, 2015; Russo & Ancillotto, 2015). But the response of bats to urbanisation may be species-specific and even vary by sex (Lintott et al., 2014) due to differing requirements (Avila-Flores & Fenton, 2005; Caryl et al., 2016; Duchamp et al., 2004; Gaisler et al., 1998; Hale et al., 2012; Lintott, Bunnefeld, Minderman et al., 2015; Russo & Ancillotto, 2015). More research is needed to better understand how different bat species respond to urbanisation and to enable more effective use of bats as broader bio-indictors of impacts on biodiversity (Russo & Ancillotto, 2015; Russo & Jones, 2015).

With recent developments in passive bat detectors, which can be left outside to automatically trigger and record bats, coupled with software for semi-automating the analysis of sound files, volunteers are now able to collect unprecedented large-scale information on bat species' distributions and activity (e.g. Newson, Evans, & Gillings, 2015). In an urban setting, volunteers are also able to provide data for gardens which can be difficult for professional biologists to access and study. Citizen science therefore offers the opportunity to assess the likely responses of bats to urbanisation.

Here, we use data collected through a large citizen science project carried out in Norfolk, UK, which provides extensive information on bat activity and occurrence for the 12 bat species present in the region (Table 1; Newson et al., 2015). This data set of over a million bat recordings collected across the urban gradient is one of the most extensive high-quality datasets for bats from anywhere in the world. Combining these data with habitat data and information on human population density, we aim to quantify how occurrence and activity are likely to change in relation to the coming decade's proposed house building. Based on evidence from other studies, we expect that the increase in housing will have a negative effect on bat activity and occurrence, especially where the housing displaces important bat habitat such as forest and ponds. We also predict that the impact will be least severe for the most widespread generalist species, such as Common pipistrelle (see Table 1 for scientific names). For each species we aim to determine hotspots of occurrence and activity and to quantify the strength of each species' avoidance of urban areas so that these can be combined to give a multi-species sensitivity map as a useful planning tool. Finally, we test the potential of different scenarios for implementing the desired house building to reduce negative impacts on bats.

2. Methods

2.1. Norfolk and the Norfolk Bat Survey protocol

Norfolk, in the southeast of the UK, borders the sea on its northern and eastern most reaches and covers 5371 km^2. The dominant habitat type of Norfolk is arable with scattered broadleaved and coniferous woodlands and towns. Additionally the area contains wetlands of international importance, saltmarsh and sandy-heathland (Dymond, 1990). The current human population size of Norfolk is 890,000 but it is projected to grow to 950,000 by 2026. The East region of England, of which Norfolk is part, is predicted to gain 530,000 people over the next 10 years, making this the fastest growing region after London with a greater projected population increase rate than England as a whole (Office for National statistics, 2014). However, compared to the other counties that constitute the East, the projected rate of population increase for Norfolk is the second lowest in the group with only Suffolk predicted to increase less. If we take the national average of 2.3 people per house (Office for National Statistics, 2011), approximately 26,087 new houses are needed in Norfolk over the next ten years to accommodate this increase.

The Norfolk Bat Survey (www.batsurvey.org) is a citizen science project with the duel aims of monitoring bat populations and enhancing engagement of the public with science and conservation. Full details of the survey's field methods, equipment and species' identification protocols can be found in Newson et al. (2015) but in summary, the survey involved coverage of 1-km squares using static full-spectrum bat detectors deployed for whole nights at three locations per square by volunteers. Detectors were set to automatically trigger and record the calls of each passing bat throughout the night, using a high pass filter of 4 kHz to define the lower bound for the triggering mechanism. Recording was set to continue until no trigger was detected for a 2 s period. We define a single recording here as a bat pass. In this paper we use data from 2013 to 2015 on bat detections in 1063 1-km different squares totalling 4559 complete nights of bat recording (Appendix A). Information was available for 12 bat species (Table 1). Sound identification of Myotis bats is difficult, and only recordings that could be confidently assigned to species were used in the analyses (see Appendix B for more details on this process). Whiskered and Brandt's bats are particularly difficult to distinguish, and therefore are treated here as a species pair. With c.20% of Norfolk surveyed per year, this survey is unique in providing data for a range of habitats including agricultural, semi-natural and different levels of urban intensity, providing a good basis for assessing the response of bats to urban cover and form.

2.2. Modelling bat distributions in Norfolk

All data analysis was conducted in R (R Core Team, 2015). For each recording location (point within 1-km square), the total number of passes for each bat species recorded during the night was calculated (the 'activity'). Additionally, these data were simplified to simple presence/absence information and the same analyses were conducted for data on bat occurrence and bat activity.

Using Centre for Ecology and Hydrology (CEH) Landcover Map 2007 data (LCM 2007, Morton et al., 2011) we calculated the percentage cover of coniferous woodland, broadleaved woodland, arable, coastal, fen/marsh/swamp, freshwater, semi-natural grassland and improved grassland in each 1-km square (defined here as site scale) in Norfolk and included these values as predictors in our