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Using multi-scale modelling to predict habitat suitability for species of conservation concern: The grey long-eared bat as a case study

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ABSTRACT

Although spatial scale is important for understanding ecological processes and guiding conservation planning, studies combining a range of scales are rare. Habitat suitability modelling has been used traditionally to study broad-scale patterns of species distribution but can also be applied to address conservation needs at finer scales. We studied the ability of presence-only species distribution modelling to predict patterns of habitat selection at broad and fine spatial scales for one of the rarest mammals in the UK, the grey long-eared bat (*Plecotus austriacus*). Models were constructed with Maxent using broad-scale distribution data from across the UK (excluding Northern Ireland) and fine-scale radio-tracking data from bats at one colony. Fine-scale model predictions were evaluated with radio-tracking locations from bats from a distant colony, and compared with results of traditional radio-tracking data analysis methods (compositional analysis of habitat selection). Broad-scale models indicated that winter temperature, summer precipitation and land cover were the most important variables limiting the distribution of the grey long-eared bat in the UK. Fine-scale models predicted that proximity to unimproved grasslands and distance to suburban areas determine foraging habitat suitability around maternity colonies, while compositional analysis also identified unimproved grasslands as the most preferred foraging habitat type. This strong association with unimproved lowland grasslands highlights the potential importance of changes in agricultural practices in the past century for wildlife conservation. Hence, multi-scale models offer an important tool for identifying conservation requirements at the fine landscape level that can guide national-level conservation management practices.

1. Introduction

The importance of scale for understanding ecological patterns and processes is widely recognised (Levin, 1992), yet conservation studies and management practices addressing multiple spatial scales are rare (du Toit, 2010). Conservation goals are scale-specific, from identifying national-level priority areas to local site habitat management, and therefore require different conservation planning approaches at different scales (Cabeza et al., 2010). Moreover, because ecosystems or populations cannot be described adequately at a single scale (Levin, 1992) and because the effect of environmental variables is scale-dependent (Collingham et al., 2000), cross-scale studies are necessary for identifying species–habitat relationships and guiding conservation planning (Graf et al., 2005; Lomba et al., 2010).

Mapping the spatial distribution of species is an important aspect of conservation biology, contributing to the management of endangered species, species reintroduction programs, ecosystem restoration, and population viability analysis (Hirzel et al., 2001). Ecological modelling techniques have been mainly used to study broad-scale patterns of species distribution despite their potential to identify fine-scale habitat suitability for endangered species (Fernandez et al., 2003). Only recently have studies applied modelling at multiple-scales to address hierarchical conservation needs within and across species (e.g., Cabeza et al., 2010).

Because absence data are often not available or are unreliable, modelling approaches that require presence-only data are particularly valuable (Hirzel et al., 2002). Recently, Maxent, a presence-only machine learning modelling approach (Phillips et al., 2006), has become the most commonly used species distribution modelling technique because it has been shown repeatedly to outperform other presence-only, as well as presence/absence modelling techniques (Elith et al., 2006; Hernandez et al., 2006). Maxent is especially advantageous when the amount of occurrence data is limited, as is the case with many rare and cryptic species (Wisz et al., 2008).

Predictive distribution modelling is especially relevant for identifying the conservation requirements and potential distribution of

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bats, because their nocturnal nature, wide home ranges, and problems with identification, render it difficult to conduct comprehensive mapping of distributions (Jaberg and Guisan, 2001; Greaves et al., 2006). Despite their high abundance and wide geographic distribution, many bat species have undergone substantial population declines throughout their range in the past century, primarily due to human population expansion and the associated increased demand for land and food (Mickleburgh et al., 2002). However, while bat roosts are protected by law in many European countries, foraging habitats rarely are (Racey, 2009). The drive to maximise food production in the past 60 years has resulted in substantial changes in farming practices with detrimental effects on biodiversity at all trophic levels (Boatman et al., 2007). Bats are likely to be particularly sensitive to the loss of important landscape elements through the removal and degradation of hedgerows and tree lines (Walsh and Harris, 1996; Boughey et al., 2011), habitat fragmentation (Bright, 1993), and the decline of arthropod prey populations as a result of agricultural intensification (Wickramasinghe et al., 2004; Conrad et al., 2006).

We studied the application of species distribution modelling to predicting the availability of suitable habitats for species of conservation concern across spatial scales, from factors that limit distribution at the broad scale to the fine-scale selection of foraging habitats within the potential distribution. Because of the scale-dependent nature of species' responses to ecological parameters, it is important to incorporate the appropriate environmental variables for the specific model scale (Graf et al., 2005). While climatic variables, like average seasonal temperatures and precipitation, vary considerably across broad spatial scales, they do not vary sufficiently at the finer, colony-level, scale to affect patterns of habitat selection. In addition, the resolution of many available eco-geographical maps (like geology and human population density) is too coarse to be included in fine-scale models.

As a case study, we used one of the rarest mammals in the UK, the grey long-eared bat, *Plecotus austriacus*. This locally rare but globally common species is widespread in southern Europe but extremely rare in countries at the northern edge of its distribution (Juste et al., 2008). The UK population is restricted mainly to the southern coast of England and appear to be in decline because several colonies have gone extinct in the past few decades (Harris et al., 1995). Not only is this species rare, but it cannot be adequately detected and identified acoustically due to its low intensity echolocation calls and the presence of a sympatric cryptic species (*Plecotus auritus*) with similar calls (Russo and Jones, 2002). Therefore, the conservation of the grey long-eared bat can especially benefit from the application of ecological modelling techniques. Lack of information on behaviour and ecological requirements has hampered the development of conservation management plans for the grey long-eared bat (Dietz et al., 2009).

This study aims to address this lack of knowledge and develop a method that will allow the identification of potential foraging grounds within the suitable range of populations of conservation concern. Our main objectives are: (1) to determine the effect of environmental variables on species distribution and habitat use at different spatial scales; (2) to evaluate the use of species distribution modelling to identify suitable foraging habitats in unstudied areas; and (3) to identify the conservation requirements of grey long-eared bats across spatial scales.

2. Methods

2.1. Study area

Broad-scale habitat suitability was modelled for the whole of the UK, excluding Northern Ireland (where the species was never recorded). The UK is at the north-western edge of the grey long-eared bat's distribution (Spitzenberger et al., 2006). For the fine-scale foraging habitat suitability study, study sites were located in areas predicted by the broad-scale model as highly suitable. We radio-tracked grey long-eared bats from two maternity colonies located approximately 160 km apart, on the south coast of Devon (50°3′N; 3°3′W) and the Isle of Wight (50°4′N; 1°2′W; Fig. 1). Both study sites were dominated by improved pasture (Devon: 38%, Isle of Wight: 37%) and arable land (22%, 32%), but included also semi-natural habitats including broadleaved woodland (9%, 8%), riparian vegetation (both 3%), and semi-unimproved meadow and marsh (3%, 11%).

2.2. Modelling procedure

We used presence-only species distribution modelling (Maxent) to predict areas that contain suitable habitats for the grey long-eared bat in the UK (broad-scale model, resolution 30 arc seconds, $\sim$1 km^2) and within the maternity colony ranges (fine-scale model, resolution 100 m^2).

2.2.1. Broad spatial scale

For the UK model we used distribution locations with a resolution of 1 km^2, obtained from the National Biodiversity Network (http://data.nbn.org.uk/), Dorset Environmental Records Centre, National Trust, and the Bat Conservation Trust. Only records from the past 30 years (1980–2010) were included in the model. To avoid pseudoreplication we removed duplicate occurrence points, using only one location record per 1 km^2 (N = 66). Models were generated using eco-geographical variables that were deemed to be ecologically relevant based on prior knowledge of the biology and annual activity cycle of temperate bats. All variables had a spatial resolution of 1 km^2. The following variables were included in the models: spring, summer and winter temperatures; temperature and precipitation seasonality (Bioclim variables that measure the extent of seasonal variability); annual and summer precipitation; altitude (WorldClim, http://www.worldclim.org); land cover (Land Cover map 2000, Centre of Ecology and Hydrology; reclassified into nine classes; Supplementary 1); geology (British Geological Survey, http://www.bgs.ac.uk/; reclassified into 23 classes); human population density (LandScan 2008 Global Population Database, http://www.ornl.gov/sci/landscan/); and night light pollution (http://www.ngdc.noaa.gov/dmsp/). Only variables that contributed to the model >1% were included in the final model.

2.2.2. Fine spatial scale

Fine-scale foraging habitat models were generated for the two maternity colonies, using the radio-tracking datasets (Section 2.3). Graf et al. (2005) found that the best scale model corresponds to the size of an individual's annual home range. In our study, individual bats could only be radio-tracked for a maximum of two weeks (the battery life of the small transmitters). As a result, the colony range, which includes the combined location fixes of all individual bats radio-tracked throughout the majority of the annual active period (April–September), was used to represent the size of the annual home range.

To obtain presence locations we overlaid in ArcGIS (version 9.2, ESRI) the core foraging areas (Section 2.3) of all radio-tracked bats. The resolution of the model was set at 100 m^2, corresponding to the resolution of the cluster analysis used to generate the core foraging areas. To avoid pseudoreplication we removed duplicate occurrence points resulting from overlapping core foraging areas between bats or several location points from the same bat, selecting one location point from each 100 m^2 cell. To test the ability of species distribution models to identify potential suitable foraging grounds around maternity colony roosts in new locations, only