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Bat use of commercial coniferous plantations at multiple spatial scales: Management and conservation implications

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ABSTRACT

Commercial plantations are primarily managed for timber production, and are frequently considered poor for biodiversity, particularly for mammalian species. Bats, which constitute one fifth of mammal species worldwide, have undergone large declines throughout Europe, most likely due to widespread habitat loss and degradation. Bat use of modified landscapes such as urban or agricultural environments has been relatively well studied, however, intensively managed plantations have received less attention, particularly in Europe. We assessed three of the largest, most intensively managed plantations in the UK for the occurrence of bats, activity levels and relative abundance in response to environmental characteristics at multiple spatial scales, using an information theoretic approach. We recorded or captured nine species; *Pipistrellus pipistrellus* and *P. pygmaeus* were the most commonly recorded species on acoustic detectors and female *P. pygmaeus* were the most commonly captured. The influence of environmental characteristics on bat activity varied by species or genus, although all bat species avoided dense stands. Occurrence and activity of clutter and edge adapted species were associated with lower stand densities and more heterogeneous landscapes whereas open adapted bats were more likely to be recorded at felled stands and less likely in areas that were predominantly mature conifer woodland. In addition, despite morphological similarities, *P. pipstrellus* and *P. pygmaeus* were found foraging in different parts of the plantation. This study demonstrates that with sympathetic management, non-native conifer plantations may have an important role in maintaining and supporting bat populations, particularly for *Pipistrellus* spp.

1. Introduction

Unsustainable exploitation of native forests is considered one of the greatest threats to biodiversity and has led to the fragmentation and degradation of forests worldwide (Anon, 2011). Demand for wood-based products is likely to increase in the future and there is a growing need for this to be met by sources other than primary forests. Plantation forests, defined as cultivated forest ecosystems established by planting and/or seeding in the process of afforestation and reforestation, are economically important worldwide as sustainable sources of wood fibre become more necessary (Carnus et al., 2003). Widespread historical deforestation, post war planting initiatives and a need for wood products meant many countries established plantations during the 20th Century. Globally, plantation forests cover 54.3 million hectares with temperate regions such as the US, Japan, Oceania and Europe accounting for >50% of plantation areas and demand for wood products is predicted to increase (FSC, 2012; Honnay, 2004). Due to their lack of structural complexity, intensive management, and often single or low species composition, plantations are often considered to be devoid of biodiversity (Bremer and Farley, 2010) although there is evidence that for some taxa this is not the case (Humphrey et al., 2003).

Maintaining and restoring biodiversity is a key tenet in sustainable ecosystem management, the paradigm currently guiding habitat management practices across Europe, North America and Australasia (Ober and Hayes, 2010; Paquette and Messier, 2009). This is driven by concern about world-wide declines in species and populations across a range of taxa (Dirzo et al., 2014) and recognition that much of this is driven by habitat loss and fragmentation, caused by anthropogenic change (Thomas et al., 2004). In many countries the timber industry has responded by shifting focus from purely timber production to one which encourages sustainable practices that promote both wildlife conservation and sustainable timber yields (FSC, 2012). In Europe this has been driven by policy change initiated as a result of the Convention of

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Biological Diversity, requiring explicit consideration of environmental, economic and social objectives and a multi-purpose approach to forestry (Watts et al., 2008)

Previous studies have suggested that species diversity will be positively influenced if management operations such as felling mimic natural disturbances, for example by creating multi-aged rather than even aged plantations (Bardat and Aubert, 2007). Multi-aged forest systems can support a higher diversity of species through the provision of different habitats for a wide range of flora and fauna, from those reliant on early successional habitats e.g. some song birds (Sweeney et al., 2010) to species dependent on mature habitats e.g. canopy dwelling Coleoptera (Ohsawa, 2007). As a result, many forest managers are moving away from practices such as clear felling (the removal of all trees within a stand, a forestry unit denoting a distinct area of woodland that is composed of uniform group of trees in terms of species composition, age class distribution and size class distribution) to more targeted harvesting approaches such as continuous cover forestry (Lindenmayer and Hobbs, 2004; Pawson et al., 2006). Other forest management practices such as retention of stands with longer rotations, leaving dead wood (Humphrey et al., 2003) and restructuring plantations have had positive impacts for a wide range of taxa (e.g. Oxbrough et al., 2010).

Bats have undergone major historical declines across many temperate regions, in part due to widespread habitat loss (Walsh et al., 1996). The majority of temperate bat species rely on forest for at least part of their life cycle (Altringham, 2013), but while bat associations with native woodlands are well established (e.g. Boughey et al., 2011; Dietz et al., 2009), less is known about use of plantation habitats. This paucity of research is perhaps in response to many habitat studies showing active avoidance of plantations by individual species (Boughey et al., 2011; Russo and Jones, 2003; Smith and Racey, 2008; Walsh et al., 1996). However, there is growing evidence from Europe (Charbonnier et al., 2016; Cistrone et al., 2015; Cruz et al., 2016; Mortimer, 2006; Pereira et al., 2016; Russo et al., 2010), New Zealand and Australia (Borkin and Parsons, 2011; Borkin et al., 2011; Burgar et al., 2015) and North America (Morris et al., 2010; Patriquin and Barclay, 2003) that suggests that bat use of plantations may be more widespread than previously assumed. While management for biodiversity and protection of European Protected Species is a key requirement for European forestry management (Boye and Dietz, 2005), the lack of broad scale studies in European plantation forests means that there is currently insufficient information for forest managers to ensure sufficient and appropriate mitigation is carried out (Russo et al., 2016). Understanding whether there are general patterns that underpin how highly mobile species make use of plantations may be an important strategy for protecting against future species declines.

Here, we examine the extent to which bat species use plantation woodlands in northern Britain by assessing the influence of various environmental characteristics on bat abundance and activity at multiple spatial scales. Specifically, our objectives were to:

1. Assess the composition of bat populations in commercial coniferous plantations.
2. Identify local and landscape scale variables which influence occurrence, abundance and activity, and how this varies between species.
3. Compare how two morphologically similar species (*Pipistrellus pipistrellus* and *P. pygmaeus*) respond to plantation characteristics.
4. Use these findings to give appropriate management recommendations.

Nine of the seventeen species resident in Britain occur within the study area, including *Myotis*, *Nyctalus* and *Pipistrellus* spp. These can be categorised into different foraging "guilds", bats with similarities in morphology, hunting technique and echolocation call structure (Schnitzler et al., 2003). Bats in the genus *Nyctalus* forage primarily in open spaces (open adapted) compared to *M. nattereri* (clutter adapted) or *P. pipistrellus* (edge adapted) and are therefore likely to respond differently to both local and landscape scale characteristics. *Pipistrellus pipistrellus* and *P. pygmaeus* are of particular interest as they are common, sympatric species which share morphological and dietary similarities (Barlow, 1997) and may use habitat selection as a mechanism for resource partitioning.

2. Methods

The study was conducted in three plantation forests in Central and Southern Scotland and Northern England (Fig. 1). We chose forests for their large size (ranging from 30,000 ha in Cowal and Trossachs to 60,000 ha in Kielder and 114,000 ha in Galloway), high productivity and the predominance of *Picea sitchensis* (Sitka spruce), the most commonly planted and intensively managed coniferous tree species in Europe (Boye and Dietz, 2005). Within each forest, multiple sites were selected using a Forestry Commission sub-compartment database within a Geographic Information System (GIS) (ArcMap 10.1, ESRI) based on stand age and species composition (Fig. 1).

In total, seven sites were surveyed in Cowal and Trossachs, 12 in Galloway Forest and 12 in Kielder Forest. Where possible, a stand of trees at each management stage (from a total of six management stages: see Appendix 1) were selected in each site, which was a maximum of 2 km^2 in size and at least 4 km from another site. Not all sites had all stands of each management stage resulting in an unbalanced design of between four and six stands per site and a total of 285 stands across 31 sites (Fig. 1).

2.1. Bat abundance surveys

For some species identification from echolocation calls is not possible (Schnitzler et al., 2003), therefore capturing individuals for inspection in the hand can be the only way to confirm species occurrence, while also allowing confirmation of reproductive status (Hill and Greenaway, 2005). We assessed relative bat abundance (number of captures per site) by placing an Austbat harp trap (2.4 × 1.8 m) and three Ecotone mist nets (2.4 × 6 m) at one location in each site to trap bats. The location was selected based on ease of access and nets were placed across potential flight lines (e.g. tracks or rides) between either two mature stands or extending from the edge of a mature stand into felled stands. Nets were placed at least 50 m from each other, with placement dictated by the plantation structure and deliberately chosen to maximise capture rates. We used an acoustic lure (The Autobat, Sussex University, Brighton, UK) with four different synthesised bat calls (*Pipistrellus* spp. mix, a mixture of *Myotis* sp., *Nyctalus leisleri* and *M. nattereri*), which has been demonstrated to greatly improve capture rates (Hill and Greenaway, 2005) and attracts a variety of different bat species present in the study area (following Lintott et al., 2013). Each call was played at each trap for 15 min, with the lure moved between traps every 30 min. Traps were checked every 15 min and any captured bats were identified to species, weighed, measured, aged, sexed, assessed for reproductive status and marked temporarily by fur clipping. All captures were carried out under licences 19,584 and 20,131,093 (Scottish Natural Heritage, Natural England)

2.2. Bat acoustic surveys

All surveys were carried out between 12th June and 3rd September 2013. We surveyed all the stands within a site simultaneously and for a single night, starting 30 min after sunset to ensure that recorded individuals would be actively foraging rather than commuting from roosts. Surveys finished 4 h later as this represents the length of the shortest night in this area during summer. Bat activity was quantified using a SongMeter SM2 Bat + (Wildlife Acoustics, Inc., Concord, MA) using two microphones at a height of 1 m and positioned at a 45 degree angle. One microphone was placed at the stand edge pointing towards adjacent tracks or rides; the other was positioned 20–40 m into the