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Selection of roosting habitats by *Nyctalus noctula* and *Nyctalus leisleri* in Białowieża Forest—Adaptive response to forest management?

I. Ruczyński [a,*], B. Nicholls [b], C.D. MacLeod [b], P.A. Racey [b]

[a] *Mammal Research Institute, Polish Academy of Sciences, 17-230 Białowieża, Poland*
[b] *School of Biological Sciences, University of Aberdeen, Aberdeen, AB24 2TZ, United Kingdom*

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ABSTRACT

Tree dwelling bats select cavities in large, old, dying or dead trees. This inevitably brings them into direct conflict with the interests of forest managers, who are trained to fell such trees. Therefore the identification of forest stands providing optimal roosting opportunities for bats is crucial, in order to provide appropriate guidelines for forest management. It is also important to identify the extent to which the roosting ecology of bats changes in response to habitat modification. Białowieża Forest (BF) offers a unique opportunity, in the temperate zone, to observe differences between areas with no direct human intervention and managed areas and in particular to reveal the effect of forest management on the roosting ecology of forest dwelling bat species. We used GIS techniques to evaluate bats' spatial response to changes in forest structure and to test the hypotheses that the forest dwelling bats *Nyctalus noctula* and *Nyctalus leisleri* prefer roost sites within old deciduous or wet woodlands over young and coniferous ones and that roost site preferences reflect the extent to which dead and dying trees are removed. There was a significant difference in the selection of roosting habitat between the managed and pristine areas of the forest. Within the pristine forest, both species displayed a strong preference for roost trees located within old deciduous stands (>100 years), whereas in the managed part of the forest old wet woodland was preferred while all medium and young forest stands were avoided. Our data reveal a high degree of lability in the selection of roosting habitat by bats. It appears that bats are able to respond to changes in their environment by changing their roost site preferences and could therefore occupy habitat previously considered less suitable.

1. Introduction

During the summer months, temperate zone bats can spend more than 20 h of each day within their roost (Jenkins, 1998). These roosts provide sites for hibernation, mating, and rearing young (Kunz and Lumsden, 2003), and may facilitate complex social interactions (Wilkinson, 1992; Kerth et al., 2001; Vonhof et al., 2004; Willis and Brigham, 2004), offer protection from inclement weather (Vaughan, 1987; Sedgeley, 2001) as well as minimising the risks of predation (Fenton, 1983; Fenton et al., 1994). Many of the 850 insectivorous bat species roost in trees (Menzel et al., 1998; Sedgeley and O'Donnell, 1999a; Boonman, 2000; Lacki and Schwierjohann, 2001; Kunz and Lumsden, 2003; Simmons, 2005) and the availability of suitable roost trees can affect not only the abundance and diversity of bat communities but also their spatial distribution (Crampton and Barclay, 1998; Russo et al., 2004). Therefore, an understanding of the roosting requirements of tree dwelling bat species is a vital component for the conservation of bats, particularly within areas where forest management practices can lead to potentially important habitats being cleared, fragmented or extensively modified.

The selection of appropriate roost sites depends on both the physical characteristics of the roost (Kalcounis-Ruppell et al., 2005; Ruczyński and Bogdanowicz, 2005; Russo et al., 2004; Sedgeley and O'Donnell, 1999a) and its surrounding features (Humphrey et al., 1997; Kerth et al., 2001; Ruczyński and Bogdanowicz, 2008). Tree dwelling bats preferentially select cavities in old, dying or dead trees (Menzel et al., 2000; Kunz and Lumsden, 2003; Sedgeley and O'Donnell, 1999b; Ruczyński and Bogdanowicz, 2008), and studies have shown that bats roost preferentially within forest stands containing a high proportion of suitable roost trees (Crampton and Barclay, 1998; Sedgeley and O'Donnell, 1999b). Such selection may decrease the costs associated with finding new tree cavities or facilitate organization of fission–fusion groups when bats switch between alternate roost locations (Lewis, 1995; Ruczyński et al., 2007; Popa-Lisseanu et al., 2008).

Ancient forest stands offer greater densities of large and decaying trees, and therefore provide more suitable roosting sites than young or mature stands (Zielinski and Gellman, 1999; Crampton and Barclay, 1998). However, their dependence on dead

* Corresponding author.
E-mail address: iruczyns@zbs.bialowieza.pl (I. Ruczyński).

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wood brings tree dwelling bat species into direct conflict with the interests of forest managers, for whom dying and dead trees constitute a threat to timber production interests because they are perceived to form a possible source of disease for neighbouring living trees. Dead and dying trees also constitute a considerable fire-risk and provide wood of low quality (Ohlson et al., 1997; Lundquist, 2003). Forest management typically involves the removal of dead and dying trees as soon as they are detected, thereby minimizing the amount of dead wood within the forest (Nilsson et al., 2002; Lõhmus et al., 2005; Czeszczewik and Walankiewicz, 2008). As a result, the management of forests for timber production could potentially have a detrimental effect on tree dwelling bat species. Current evidence indicates that such management reduces the availability of roosts for many tree roosting species (e.g. Vonhof and Barclay, 1996; Crampton and Barclay, 1998; Herr and Klomp, 1999; Law and Anderson, 2000). The reduction of available roost trees can, in turn, limit the distribution of bat species and reduce local abundance. Similarly, the reduction in the quality of roosts following habitat modification associated with forest management practices can influence levels of mortality and reproductive success (Brigham and Fenton, 1986). Therefore the identification of optimal roosting habitats for bat species is crucial in order to implement appropriate guidelines for forest management. However, roost switching is common in bats (Lewis, 1995; Kunz and Lumsden, 2003) and it has been shown that roost site preferences can change in response to ambient conditions (Kerth et al., 2001; Ruczyński and Bogdanowicz, 2008). Therefore, it is important to identify the extent to which the roosting ecology of bats changes in response to habitat modification, and particularly anthropogenic modification. In particular habitats previously identified as unimportant or marginal to bats may increase in importance with modified forest management practices.

The present study was carried out in the Białowieża Forest (BF) (NE Poland), where patches of primeval lowland temperate forest, untouched by forestry operations, have survived (Tomiałojć et al., 1984; Faliński, 1986). This offers a rare opportunity, in the European temperate zone, to observe differences between areas with no direct human intervention (which can therefore act as 'controls') and managed areas (which can act as 'experimental' sites), and can therefore give an indication of the effect that forest management has on the roosting ecology of forest dwelling bat species. The present study focused on two particular bat species found in the study area: *Nyctalus noctula* (Schreber, 1774) and *Nyctalus leisleri* (Kuhl, 1817).

N. noctula and *N. leisleri* are closely related species (Salgueiro et al., 2007) which are sympatric over much of their ranges. *N. noctula* is one of the most common forest dwelling species in Europe, whereas *N. leisleri* is relatively rare (Bogdanowicz, 1999; Bodanowicz and Ruprecht, 2004; Shiel, 1999) except in Ireland, where *N. noctula* does not occur (O'Sullivan, 1994). *N. leisleri* is also more limited to ancient forests (Bodanowicz and Ruprecht, 2004). In both taxa, pregnant and lactating females typically roost in tree cavities (Gebhard and Bogdanowicz, 2004; Strelkov, 2000).

The aims of the present study were to investigate: (1) roost site selection by *N. noctula* and *N. leisleri* in relation to tree species dominance, and age of forest stand surrounding roost trees, (2) inter-specific differences in roost site selection and (3) differences in the selection of roosting habitat by bats roosting within managed and pristine areas (strict reserve of Białowieża National Park) within the forest. We tested the following hypotheses: *N. noctula* and *N. leisleri* will select roost trees within forest stands offering the highest proportion of available roosting cavities, i.e. old, deciduous stands. Bats will alter their roost site preferences in response to anthropogenic modification that reduces the proportion of available roosting cavities, i.e. the removal of dead and dying trees.

2. Materials and methods

2.1. Study area

Białowieża Forest (BF) is located at the Polish–Belorussian border (approximately 52°43′N, 23°54′E) and covers an area of 1450 km^2. It is the largest remnant of original temperate forest in Europe. The study area (approximately 100 km^2) covers the well-preserved stands of the strict reserve within Białowieża National Park (BNP, hereafter referred to as pristine stands) (47.5 km^2) and an extensive area (>570 km^2) of managed forests with old growth remnants (trees > 100 years old) within them. Large-scale timber extraction began in the forest less than a 100 years ago, and the currently managed fragments did not initially differ from the retained parts in terms of climate, soil, history or plant and animal communities at this time (Faliński, 1986; Bobiec et al., 2000; Tomiałojć and Wesołowski, 2004). The old-growth stands preserved in the strict reserve of BNP consist of multi-storied, unevenly aged, mixed tree species (the tallest spruces grow up to 57 m and several other species reach 42–45 m). The old growth stands are further characterised by large amounts of dead timber and uprooted trees (Wesołowski and Tomiałojć, 1995). These stands are dominated by oak *Quercus robur* (20% of the area), hornbeam *Carpinus betulus* (19%), spruce *Picea abies* (16%), alder *Alnus glutinosa* (12%), pine *Pinus sylvestris* (11%), lime *Tilia cordata* and maple *Acer platanoides* (9%), birch *Betula* spp. and poplar *Populus tremula* (7%), and ash *Fraxinus excelsior* (6%). In the managed part of the forest, there is a lower percentage of deciduous trees: oak (11% of the area), hornbeam (2%), alder (20%), lime and maple (0%), birch and poplar (12%), ash (2%), and a greater proportion of conifers: pine (26%) and spruce (28%; Jędrzejewska and Jędrzejewski, 1998). In addition, there are fewer older trees and many areas where trees have a similar upper age-limit in the managed forest, reflecting when they were previously harvested.

2.2. Capture of bats and location of roost trees

Roost sites were located from May to August 1998–2000 and 2002 (*N. leisleri*), and in 1999–2002 (*N. noctula*). Bats were captured in mist nets (2 m × 6 m and 2.5 m × 4 m) set across small rivers in the forest and at one pond (6 capture sites in total). Captured bats were classified by species, sex, age (juvenile or adult), and reproductive status. Roost trees were located by tracking bats with radio-transmitters (0.5 g – Biotrack, Wareham, UK, and Titley Electronics, Ballina NSW, Australia; or 0.7 g – Titley Electronics and Holohil Systems, Carp, ON, Canada) affixed to the inter-scapular region with rubber adhesive (Skin-Bond, Smith and Nephew®, Largo Florida, USA). Transmitter mass represented <5% of the body mass of bats (Aldridge and Brigham, 1988). Altogether, 26 *N. noctula* and 25 *N. leisleri* were tracked using 2-element Yagi antennae and receivers (Yupiteru MVT-700, Javiation, Bradford, West Yorkshire, United Kingdom; Yaesu FT-290R, Vertex Standard, Cypress, California). Bats emerging at dusk were counted to determine the number of individuals in each roost. In most cases each species roosted separately. Tagged bats were located daily for the life of transmitters (up to 14 days). Methods conformed to guidelines approved by the American Society of Mammalogists (Gannon and Sikes, 2007).

2.3. Data sources

Geographical position of roost sites was recorded using a GPS-receiver in 2008, with an accuracy of <15 m (Garmin GPSmap60cSx). Habitat data were extracted from the official inventory and management plans of the local forestry authorities (Białowieża, Hajnówka) and those of BNP (map scale 1:20 000).