Conservation of bats in British woodlands

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Conservation of bats in British woodlands

David A Hill and Frank Greenaway

Broadleaved woodlands are probably the most important of British habitats for bat conservation. For most of the year they support a great variety and abundance of invertebrates for bats to feed on. They also offer a huge selection of tree cavities – crevices, bark flaps, fissures and woodpecker holes – where bats can rest during the day and where females can gather in maternity colonies, to give birth and nurse their young. All 16 British species of bat make regular use of trees and wooded areas, and some of our rarest bats are woodland specialists.

Yet, in spite of their importance, there is a distinct lack of knowledge about bats in woodlands. Even most bat specialists know much less about the distribution, behaviour or conservation status of bats inhabiting woodlands than about bats that roost in buildings or caves. The main reason for this is that bats are particularly difficult to find or record in woodlands, which has made them very hard to survey or study.

In this article we describe a technique which we have developed that overcomes some of these difficulties and makes it possible, for the first time, to survey woodlands for bats in a systematic way. In 2005 and 2006, we used this technique to survey bats in woods in the south-east of England. The results of those surveys strongly suggest that the number of bats and diversity of species found in a woodland are related to the predominant tree species and the structure of the wood. We shall summarise these findings, discuss some of their implications for woodland management, and conclude by arguing that woodlands should become a major focus of future efforts to monitor bat populations and promote their conservation.
Conservation of bats in British woodlands

Current status of bats and woodlands

Bat populations have declined in Britain, as they have in many other parts of the world (reviewed in Racey & Entwistle 2003). In most cases, it is impossible to quantify the scale of the decline because of a lack of reliable historical data on population sizes or distributions. But the accumulated evidence provides a compelling argument that numbers of most British bat species, and the ranges of some, have shrunk substantially, notably during the last century (Harris et al. 1995). In recent years, populations of Greater and Lesser Horseshoe Bats Rhinolophus ferrumequinum and R. hipposideros have shown signs of increasing, but there is no evidence of recovery in populations of other species (BCT 2006). In recognition of the declines and the continuing threats that they face, all British bat species and their roosts are now protected by national and European legislation.

A variety of factors is thought to have contributed to the decline of bat populations, including the loss of roosting sites and hibernacula, and the loss and degradation of feeding habitats. One habitat which has suffered major losses is woodland. Broadleaved woods once covered most of the British Isles, but the total area has been decreasing since widespread clearance of land began in the Neolithic era. Loss of semi-natural woodlands has continued into modern times, reaching a low point at the beginning of the 20th century, when only 5.4% of Britain’s land area supported woodland. Woodland now occupies a total of 13.1%, but more than half consists of planted conifers. Broad-leaved woodlands cover just 5.6% of Britain, and much of that is in small fragments scattered across the landscape (statistics from Forestry Commission 2007 and Watts 2006).

Given their importance to bats, and the fact that they have been in decline, broadleaved woodlands would seem to be an obvious target on which to focus bat conservation work. In fact, this has not been the case. Although efforts to survey bats and promote bat conservation in Britain have gained considerable momentum over the past 15 years, relatively little has been done to assess bat populations, or their habitat requirements, in woodlands. Even the National Bat Monitoring Programme (see Box 1), which is a major initiative to survey Britain’s bats, has placed little emphasis on bats in woodlands. The reason for this is very simple: bats are extremely difficult to study, or even to find, in woodlands by means of standard techniques.

Surveying methods for bats

Being small, fast-moving and most active during the hours of darkness, bats are generally difficult to survey. One of the most common methods is to count individuals as they exit from a communal roost site. This can be particularly useful with species that form maternity roosts in buildings, as they commonly use the same roost site year after year. The bats leave the roost around dusk on most days, and often via one or two defined exit points. In most cases it is possible to watch and count the bats as they emerge without entering the roost and with little danger of causing disturbance. As the method is non-invasive, no licence is required. This means that surveys can be conducted by volunteers, and counts can be safely repeated several times in a season, as well as in successive years.

Bats can also be surveyed by monitoring the ultrasonic calls which they produce for echolocation. These can be converted to audible sound by using a portable bat-detector. Different bats give different kinds of calls and, in many cases, the species of bat can be identified from characteristics of the calls. However, identification to species is not always possible because bats often adjust the structure of their echolocation calls in relation...

Box 1 The National Bat Monitoring Programme

In 1995, the Bat Conservation Trust initiated a five-year programme of research to develop and apply methods for systematically monitoring bat populations in the UK. Data collection began in 1996 and has continued annually since. The National Bat Monitoring Programme (NBMP) uses trained volunteers from local bat groups to make annual surveys of specific sites throughout the UK. The main methods used are winter counts of bats at hibernation sites, counts of bats emerging from known maternity roosts, and field and waterway surveys with bat-detectors. Different methods are suited to different subsets of species. Emergence counts focus on colonies of six species roosting in buildings. The field surveys focus on four species – Noctule Nyctalus noctula, Serotine Eptesicus serotinus, Common Pipistrelle and Soprano Pipistrelle – and the waterway survey on Daubenton’s Bat Myotis daubentoni. Two woodland bats, Natterer’s Bat and the Brown Long-eared Bat, are surveyed, but only those colonies that roost in buildings. Woodland habitats are not a focus of the NBMP, presumably because of the extreme difficulties involved in surveying them, as explained in the main text.
to the environment in which they are flying, and there is some overlap between the calls of different bat species under certain conditions. Nevertheless, it is an extremely useful non-invasive method for identification of bats in flight, and for obtaining comparable measures of bat activity. In recent years, several inexpensive bat-detectors have become available and the monitoring of echolocation calls has now become one of the main methods used to survey patterns of activity and habitat use by bats.

Both of these methods are difficult to use in woodlands, for a variety of reasons. In woodlands, roosts are usually in holes and cracks in trees or under loose flaps of bark. A maternity colony usually uses the same roosts in consecutive years, but it may use several roosts in a season, moving to a different one every few days or so. In many cases, whether occupied or not, roost sites are indistinguishable from a multitude of other holes, cracks and crevices in trees that are not used by bats. So, visual searching for tree roosts in woods is not a viable method.

Bat-detectors are also less useful in woodlands than in more open habitats, because bats flying in a cluttered environment normally give quiet echolocation calls. Also, in these conditions, several species use calls that are very similar in structure, so that, even when their quiet calls are detected, species identification can be difficult or impossible. In these cases, it is necessary to catch the bats to identify species unambiguously. Once caught, they can also be examined to determine sex and reproductive condition. This is important information, as the presence of a reproductive female indicates that there is a maternity colony in the vicinity, whereas the presence of a male does not. Unfortunately, bats are also quite difficult to catch inside woodlands. The ‘traditional’ method is to try to catch them by setting mist nets or harp traps over paths and rides or over small streams. However, while some species routinely use such features for commuting routes or for foraging, others do so infrequently and so are much less likely to be caught. What is really needed is a method for catching bats inside the interior of the wood itself, and ideally one that will attract bats down from the canopy. And this is what we have developed.

**Lured by the siren’s call**

Our technique involves using simulated bat calls as a lure so that the bats can be captured. As well as the ultrasonic echolocation calls used to navigate and to locate prey, bats produce a variety of other vocalisations, which are thought to be used to communicate with other bats. These calls, commonly referred to as ‘social calls’, usually include lower frequencies than echolocation calls, and some are even audible to humans. They are also given less frequently than echolocation calls, and at irregular intervals. Work on the function of social calls is still at an early stage, but indications are that the way in which other bats respond to them depends on the type of call and the context in which it is given. For example, when recordings of Common Pipistrelle *Pipistrellus pipistrellus* social calls were played back, they appeared to repel other bats from feeding areas when insect...
prey was in short supply, but not when it was plentiful (Barlow & Jones 1997). By contrast, ‘alarm calls’ given by Common Pipistrelles can be used to elicit an approach response from other bats of the same species, possibly representing a form of predator-mobbing behaviour (Russ et al. 1998).

We wondered whether social calls could be used to attract woodland bats into a mist net or harp trap, in much the same way as some bird-ringers use recordings of birdsong to lure birds. Most of the species that are difficult to catch in woodlands give social calls much more rarely and unpredictably than do Common Pipistrelles. This makes it very difficult to obtain good-quality recordings for use in playback. As an alternative, we developed a programmable ultrasound synthesiser, the Sussex Autobat, that we use to produce simulations of bat social calls. Our preliminary work indicated that the calls produced by the Autobat could be very effective in attracting a variety of bats in woodlands, and we went on to demonstrate this experimentally (Hill & Greenaway 2005). Over 16 nights at different woodland sites, 23 bats were caught while the Autobat calls were playing, compared with only one bat caught when the Autobat was silent. The stimulus call used in this experiment was modelled on a social call of the rare Bechstein’s Bat Myotis bechsteinii, which had proved impossible to survey with other methods (Hill & Greenaway in prep.). The calls proved effective for attracting Bechstein's Bats, but we also caught bats of three other species: Brown Long-eared Bats Plecotus auritus, Whiskered Bats Myotis mystacinus, and Soprano Pipistrelles Pipistrellus pygmaeus. Having demonstrated the effectiveness of the Autobat lure for catching bats in woodlands, the next step was to apply the technique across a large sample of sites to demonstrate how it could be used to conduct systematic surveys of woodland bats at a regional level.

**Preliminary surveys of bats in woodlands of south-east England**

In 2005 and 2006, we used the Autobat to conduct two systematic surveys of bats in woodlands in south-east England. In the first, we looked at sites scattered across the counties of Hampshire, Surrey, West Sussex, East Sussex and Kent. Then, in 2006, we made a more intensive survey of East and West Sussex, with the aim of having survey data for one wood in every 10km square in which a suitable site could be found. In both cases the primary target was the rare Bechstein’s Bat, and the detailed results for this species are described elsewhere (Hill & Greenaway in prep.). However, in both surveys we caught a variety of species that were attracted to the lure, and this provided a unique set of data on variation in bat diversity in relation to woodland quality.

The protocol used in both surveys was as follows. Within each target wood, two survey sites were selected that were at least 200m from each other and 20m from the nearest woodland edge. On the survey night, a 6m net was set at one of the two sites and surveying began one hour after civil twilight. The Autobat speakers were mounted on a pole about 2m above the ground, halfway along the length of the net and about 50cm away from it. Three different sequences of stimulus calls were played in succession, two modelled on calls of Bechstein’s Bat and one on calls of the Barbastelle Barbastella barbastellus. Each call sequence was played for two minutes and followed by a 30-second interval of silence. This was continued for 1.5 hours at the first site, after which the equipment was moved to the second site, which was likewise surveyed for 1.5 hours. In cases of heavy rain, or when the temperature dropped below 10°C, sampling of the second site was completed on a subsequent night. For all bats captured a record was made of species, sex, whether adult or juvenile, reproductive status of adults and the forearm length (measured with dial callipers).

All woods that were surveyed for bats were visited again during daylight hours to make a basic classification of the woodland, in which we used predetermined categories based on the predominant canopy species, percentage canopy cover and percentage understorey cover. These were determined by walking the perimeter of the woodland block and one or more paths that crossed the interior. For very large woodland blocks, the vegetation was surveyed over an area of approximately 2.5ha that included the two netting sites.

**The 2005 survey**

From June to August of 2005, a wood was surveyed in each of 52 10km squares scattered fairly evenly across Hampshire, Surrey, West Sussex, East Sussex and Kent. The selecting of the target woods was done by Dr Patrick Fitzsimons in collaboration with Forest Research at Alice Holt.
It involved the use of three GIS database resources: the National Inventory of Woodland and Trees, the Ancient Woodland Inventory and Ordnance Survey maps. For each square, a wood was chosen that was larger than 25ha, and that appeared to have a high proportion of broadleaved trees. Other criteria used to select woods were a record of the site in the Ancient Woodland Inventory, presence of, or proximity to, surface water and proximity to other areas of woodland.

**Characteristics of the surveyed woods**

The 52 sites surveyed included a great variety of woodlands, in terms of both predominant tree species and structure of the wood. The GIS databases used in the selection process provided limited information on the nature of the woods. It was not possible to distinguish, for example, between a young, even-aged Beech *Fagus sylvatica* plantation and a mature semi-natural oak *Quercus* woodland. Eight woodland types were distinguished on the basis of predominant species in the canopy (Fig. 1). Three predominant tree species accounted for over three-quarters of the woods surveyed: predominantly oak (42%), predominantly Beech (23.1%) and predominantly Sweet Chestnut *Castanea sativa* (11.5%). At two sites planted conifers were the predominant canopy species, although both also contained areas of broadleaved trees.

**Table 1** Bats captured during July and August 2005.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Woods with species</th>
<th>Number of bats</th>
<th>m:f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Long-eared *</td>
<td>32</td>
<td>62</td>
<td>1:1</td>
</tr>
<tr>
<td>Natterer’s*</td>
<td>14</td>
<td>27</td>
<td>4:1</td>
</tr>
<tr>
<td>Whiskered*</td>
<td>10</td>
<td>19</td>
<td>2:1</td>
</tr>
<tr>
<td>Bechstein’s*</td>
<td>8</td>
<td>15</td>
<td>1:9</td>
</tr>
<tr>
<td>Brandt’s*</td>
<td>2</td>
<td>4</td>
<td>2:1</td>
</tr>
<tr>
<td>Daubenton’s</td>
<td>2</td>
<td>4</td>
<td>1:1</td>
</tr>
<tr>
<td>Common Pipistrelle</td>
<td>6</td>
<td>12</td>
<td>6:1</td>
</tr>
<tr>
<td>Soprano Pipistrelle</td>
<td>3</td>
<td>5</td>
<td>3:0</td>
</tr>
<tr>
<td>Noctule</td>
<td>2</td>
<td>4</td>
<td>1:3</td>
</tr>
<tr>
<td>Serotine</td>
<td>1</td>
<td>2</td>
<td>1:1</td>
</tr>
<tr>
<td>Barbastelle</td>
<td>1</td>
<td>2</td>
<td>1:0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>143</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Bats captured in 2005*

Bats were caught in 45 (87%) of the woods surveyed. In total, 143 bats of 11 species were caught (Table 1). The first five species listed in Table 1 are usually associated with woodland habitats, and will be referred to as ‘woodland bats’ in the discussion below. Unsurprisingly, four of these woodland bats were caught in the greatest numbers, and in the largest number of woods. Of these, Brown Long-eared Bats accounted for more than half of the bats captured, and were caught in almost two-thirds of the woods. The next most frequently caught species was Natterer’s Bat *Myotis nattereri*, which was caught in over a quarter of woods, followed by the Whiskered Bat.

Ten Bechstein’s Bats were caught in eight woods, and all of these were new records for this rare and elusive species. Nine of the ten were adult females. This means that there is likely to be a breeding colony nearby, as females rarely travel far from the maternity roost and are reluctant to cross open ground. The maximum number of bats caught in...
Conservation of bats in British woodlands

one wood was 13, with a mean capture rate of 4.4 bats per wood. More than one species was caught in over half of the woods surveyed (Fig. 3), with a maximum of five species caught in one wood, and a mean of 1.6 species.

There were no apparent associations between the extent of canopy cover and the number or diversity of bats captured. However, this result should be interpreted with caution, as the sample included very few woods with sparse canopy, and the vast majority of surveyed woods had canopy cover of 50% or more.

By contrast, there were associations between bats captured and the extent of cover in the understorey. When woodland species were considered separately, there was a positive correlation between understorey cover and the number of bats captured \( r=0.274; p=0.049 \), and a much stronger correlation with the number of species captured \( r=0.413; p=0.002 \). When all bat species were included in the analysis there were still positive correlations, but they did not reach statistical significance.

Only oak and beechwoods were sampled in sufficient numbers to allow statistical comparisons to be made of the numbers and diversity of bats caught in them. There was no significant difference in the number of bats caught in the two types of wood. However, the number of species caught in oakwoods was significantly higher than that in beechwoods \( t\text{-test}: t=2.26, df=32, p=0.031 \). This difference was stronger when only the number of woodland bat species was considered \( (t=2.4, df=32, p=0.022) \).

There was less understorey cover in the beechwoods than in the oak, which may explain some of the difference. Unfortunately, the sample sizes were too small to allow us to control for the effect of understorey, but experience at a variety of other sites leads us to conclude that oakwoods really do support a greater diversity of bat species than do beechwoods, irrespective of understorey cover.

The 2006 survey

The results from 2005 suggested that oakwoods with good canopy cover and a well-developed understorey were associated with the highest numbers of individuals and species diversity of bats. In the following year we decided to make a more comprehensive survey of Sussex, focusing, so far as possible, on woodlands with these characteristics. We wanted data for a wood in every

Figure 3 Distribution of number of species caught per wood.
Conservation of bats in British woodlands

16km square in East and West Sussex. As the main aim of the exercise was to maximise our coverage of squares in Sussex with survey data for breeding populations of Bechstein’s Bat, we decided not to resurvey any square for which we already had a record of one or more female Bechstein’s Bats. For each of the remaining squares, potential woodland sites were identified from OS maps, and woods were then visited to establish which most closely matched the required characteristics.

Characteristics of woods surveyed
Of the 39 squares considered, 11 had no suitable woodland sites and for one we were unable to obtain permission to survey. A wood was surveyed in each of the remaining 27 squares. On the whole, we were successful in finding woods that matched the characteristics for which we were looking. In 23 of the woods the canopy was predominantly oak, and in the remaining four the canopy was a mix of oak and other species. All of the woods had 50% or greater canopy cover (Fig. 4), and over three-quarters had 50% or greater cover in the understorey.

Bats captured in 2006
In total, 128 bats of 11 species were caught in the 2006 survey (Table 2). One or more bats were caught in every wood surveyed. The four species caught in the greatest numbers, and in the greatest number of woods, were same as in the 2005 survey. Brown Long-eared Bats accounted for almost half of the bats captured, and were caught in almost three-quarters of the woods. The next most frequently caught species was Bechstein’s Bat, which was caught in 44% of woods, followed by the Whiskered Bat and Natterer’s Bats, both caught in about one third of the woods.

Both the mean number of bats and the mean number of species caught per wood were greater in 2006 than in 2005. These differences were statistically significant both for all bat species (species: t=3.4, p=0.001; number of bats: t=3.76, p<0.001) and for woodland bats alone (species: t=2.88, p=0.005; number of woodland bats: t=2.98, p=0.002). For two of the main woodland species, the catch in 2006 also included a higher proportion of females than in the 2005 survey. This trend was significant for Natterer’s Bats (Chi sq.=5.33, p=0.02), but not quite for Brown Long-eared Bats (Chi sq.=3.39, p=0.07).

Woodland structure and the bat community
The two surveys were done at the same time of year and using the same survey methods. The same species were caught in both years, and yet the 2006 survey yielded both greater numbers and greater diversity of bats per wood. The fact

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<tbody>
<tr>
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<td>5</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Soprano Pipistrelle</td>
<td>5</td>
<td>19</td>
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</tr>
<tr>
<td>Noctule</td>
<td>3</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Serotine</td>
<td>2</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Barbastelle</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Bats captured during July and August 2006. * = ‘woodland bats’

In the 2006 survey, Brown Long-eared Bats accounted for more than half of the individuals captured. Frank Greenaway
that more females were caught is also indicative of higher-quality habitat, as breeding females appear to be more demanding in their habitat requirements than are males (Senior et al. 2005; Hill & Greenaway in prep.). A major difference between the two years was in the nature of the woods surveyed. In 2005 the sites selected from GIS data were heterogeneous in both predominant tree species and degree of cover. By contrast, in 2006, sites were selected by visiting several potential woods in advance. We set out to target oakwoods with good cover in both canopy and understorey layers, and the vast majority of the sites which we surveyed fitted this description. The extent to which each of these characteristics influences the bats present in a wood cannot be determined from our data. Nevertheless, it seems clear that overall the woods which we selected for the 2006 survey represented better-quality habitat for bats than those we surveyed in 2005.

The most striking feature of the results was the clear association between a well-developed understorey and the number and diversity of woodland bat species. Why should woodland bats apparently favour habitats with a well-developed understorey? There is probably no one answer for all species concerned. However, three possible factors should be considered.

1) Understorey cover provides protection from aerial predators hunting within the wood. Three of the woodland bats feed primarily by gleaning, often flying slowly or hovering to catch their prey, and may be vulnerable to predators such as the Tawny Owl Strix aluco.

2) The understorey may provide a habitat for key prey species for the bats.

3) The presence of the understorey produces a more benign microclimate than would be found without it, by acting as a baffle to reduce wind speeds within the wood, and generally maintaining a higher temperature than that outside the wood (see Greenaway 2001).

An alternative explanation would be that there was no great difference in bat communities in the different woodlands, but that bats were simply easier to capture in the clutter of the understorey than in open woodland, because they were less able to detect the net. Although we cannot test this from the current data, our strong impression is that it is not the case. On the basis of extensive experience of surveying woodlands with a variety of techniques, including monitoring activity around Autobats with infrared video and bat-detectors, we are sure that this link between understorey and bat diversity and numbers is a real one.

Implications of the findings for woodland management

Management of semi-natural habitats in Britain for conservation tends to follow established guidelines that have been developed with particular species groups in mind. Such practices may not always be beneficial to other groups. There is a widely held view that the conservation interest of many woodlands can best be maintained or enhanced by a return to traditional management practices, such as rotational coppicing, or restoration of wood pasture (see e.g. Warren & Thomas 1992; Barkham 1992; Fuller & Warren 1995).

A common prescription is to let the light into the wood, for example, by thinning or clearing the understorey, and widening rides and glades. While this is clearly necessary for conservation of some groups, such as woodland butterflies and many plants, it is not beneficial for all woodland wildlife. For instance, Hambler & Speight (1995) noted that many less charismatic woodland inver-
tibrates that depend on dark damp conditions would not be favoured by this approach. Similarly, Barbastelles have been shown to choose tree roosts that are surrounded by thick understorey (Greenaway 2001), and may abandon roosts if the understorey is cleared.

The results of this survey strongly suggest that the entire community of woodland bats may be adversely affected by the clearance of understorey. Consequently, reinstatement of traditional management practices in a ‘neglected’ woodland should be undertaken only after the site has been thoroughly surveyed for bats. Furthermore, the likely negative impact of management on bat populations and diversity should be explicitly acknowledged in any management plan for a semi-natural woodland that involves substantial changes to the structure of the canopy or understorey.

Looking to the future

This study has demonstrated that the Sussex Automatic Lure acoustic lure system opens up great possibilities for rapid survey of woodland bats. Its use makes it possible to conduct systematic surveys of woodland bats over an extensive area within a single season. Because the primary goal of the survey reported here was to search for Bechstein’s Bat, the calls we used were limited. We have developed a range of calls which, used in rotation, can increase the mean diversity of bat species caught on a single survey night. Applied in a systematic way, this method would allow rapid assessment of woodland bat diversity in relation to woodland size, structure and other characteristics over a large area within a workable timeframe.

Like many sampling methods, the inherent biases are unknown. For example, some species may respond to the acoustic lure much more readily than others, so between-species comparisons of abundance within a wood may not be justified. However, within-species differences in capture rates, whether at different sites, at the same site over time, or before and after management, are likely to reflect actual differences in abundance. This means that, for the first time, we can collect meaningful baseline data on the distribution of woodland bat species in relation to habitat quality, and we can begin to look at the diversity and structure of woodland bat communities. By repeating systematic surveys at intervals of several years, it should be possible to assess whether woodland bat populations are stable, declining or perhaps increasing. This would add a new and important dimension to the national survey approach, which currently concentrates on bats in buildings, underground hibernation sites, waterways and edge habitats.

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