**Our Ref:** 06S.JA0040
**P.A.Reg.Ref:**

**Your Ref:**

An Bord Pleanála

Elizabeth Davidson
Friends of Massy's Wood
Mount Venus House
Mount Venus Road
Rathfarnham
Dublin 16

10th January 2018

**Re:**
Dublin Mountain Visitors Centre and all associated works
in the:
Townlands of Mountpelier, Killakee and Jamestown in South Dublin.

Dear Madam,

An Bord Pleanála has received your recent submission in relation to the above mentioned proposed development and will take it into consideration in its determination of the matter.

Please note that the proposed development shall not be carried out unless the Board has approved it or approved it with conditions.

Please quote the above mentioned An Bord Pleanála reference number in any correspondence or telephone contact with the Board.

Yours faithfully,

pp Shaun Migue

Kieran Somers
Executive Officer
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The Secretary
An Bord Pleanala
64 Marlborough St
Dublin 1

Date: 5.1.2018



RE:

| | |
|---|---|
| **Development** | Dublin Mountains Visitor Centre-Strategic Development Initiative |
| **Location** | Hellfire Club/Montpelier Hill/Massy's Wood |
| **Applicant** | South Dublin County Council |
| **Reference Number** | 06S JA0040 |
| **Agent** | Elizabeth Davidson |
| | Friends of Massy's Wood<br>Mount Venus House, Mount Venus Road,<br>Rathfarnham, Dublin 16. |

**Timeline of Project**

**31.7.2017** Original Application for the above project lodged with An Bord Pleanála.
An Environmental Impact Assessment Screening determination was previously made by An Bord Pleanála in respect of the proposed development. The reference for this screening determination is 06S.JD0027.

**Number of Submissions:** 84 Submissions lodged with An Bord Pleanála regarding above project.

**9.10.2017** Further information was requested by An Bord Pleanála from applicant.

"This Department believe that Massy's Woods and the Hellfire Club plantation are likely to support birds such as long eared owl, woodcock, peregrine falcon and possibly nesting merlins. Peregrine falcons and merlins are special conservation interests for the Wicklow Mountains SPA, therefore any impacts on these two species at this site could result in ex-situ impacts on the SPA. The EIS has not included any survey for birds, so it is not clear therefore, whether merlins nest on the site or not, and therefore whether there is potential for ex-situ impacts or not".

The Department also refers to the fact that it is envisaged that the proposed new visitor centre could form a starting point for the Dublin Way route. The Department refers to the issue of cumulative impacts on the nearby sites of the Glenasmole Valley SAC (Site Code 001209), the Wicklow Mountains SAC (Site Code 002122) and the Wicklow Mountains SPA (Site Code 004040), which need to be assessed cumulatively in terms of any increase in visitor numbers, and how they may impact on the conservation objectives of the three European sites.

The applicant is requested to address the above comments in relation to birds and cumulative impact, and provide further information and clarification on such matters. Please note that any conclusions made in regard to screening for Appropriate Assessment should be set out clearly with details of sources of information/frequency of surveys/days etc. identified. Should such further considerations conclude that significant effects cannot be ruled out/are likely to have significant effects on any European Site, in view of the sites' Conservation Objectives, then a Natura Impact Statement will be required to accompany the application for approval.

Friends of Massy's Wood (FOMW) has been in existence for 25 years. FOMW joined with local residents and community groups to facilitate the community in rallying against this proposed project. To date we have received over 12,000 signatures objecting in the strongest possible terms to the suggested 15+million Flagship Development at the Hellfire and Massy's Wood.

Dear Sir,

Friends of Massy's Wood would like to object to the above development.

In relation to the response made by South Dublin County Council in November 2017 in respect of Further Information requested by the Board on 9th October 2017 Friends of Massey's Wood have a number of observations and submissions to make. In addition to the points made at first instance Friends echo the concerns expressed by the Department of Culture, Heritage and the Gaeltacht. Briefly put, these concerns relate to the impact from the proposed development on flora and fauna and the potential impact on surrounding European Sites. Despite a lengthy letter from the Department which formed the subject of the Board's FI request, it is frankly astonishing that SDCC has, in essence, simply dismissed the Department's concerns and has failed or refused to engage with the clear necessity to evaluate and identify the impact from the proposed development on the environment. Without prejudice to that general point Friends proposes to address each subject in turn;

**Birds**

The Department has expressed concern that the proposed development may impact on peregrine falcon, woodcock, merlin and long-eared owl which may be found at the proposed development site or surrounding areas. The Department specifically identified a concern that the development may lead to ex-situ or off-site impacts on peregrine falcon and merlin which are conservation objectives for the Wicklow Mountains National Park. The Department specifically drew attention to the fact that the EIS did not include *"any survey for birds"* and that therefore the developer could not say whether any merlin were in fact present on the site, use the site or may be subject to ex-situ impacts. In the absence of any survey information the same observation presumably applies equally to the each of the other three species of concern identified by the Department (peregrine, woodcock and long-eared owl). Peregrine Falcon and Merlin and Annex 1 species for the purposes of the Birds Directive and are entitled to strict protection throughout their range.

Rather than address the significant lacunae identified by the Department by, for example carrying out an appropriate survey to identify the presence of avifauna on or around the site it is absolutely remarkable that the developer has reverted in the same laconic fashion which it prepared its original application. For example it notes (p. 2) of its response simply that (emphasis added throughout);



*"Long eared owl and Woodcock are* ***potentially present*** *in the Hell Fire / Massy's Wood area. These areas of woodland are unlikely to support nesting sites of the species because of the current levels of disturbance".*

In the same vein in relation to Peregrine Falcons and Merlin the FI response states; *"Peregrine and Merlin are special conservation interests of the Wicklow Mountains therefore the only species relevant to the AA screening.* ***Both species are likely to hunt within the site.*** *The site does not provide suitable nesting habitat for Peregrine (cliffs and tall buildings). Merlin may nest in conifer plantations, however given that there are vast areas of heath and blanket bog, the preferential nesting habitat of Merlin close by the conifer plantations are unlikely to provide an important nesting resource for this species".*

In other-words, the Department has raised a specific query in relation to the four species and has stated that in the absence of any survey information, the species may be present and there may be an impact on them at the site. The Developer, rather than addressing that concern, has responded by admitting that the species of concern are (or, more accurately, are likely to be as it does not have any hard information by which this could be verified) present on site but because of a perceived unlikelihood by those species to utilize the affected section of the site no question of disturbance arises.

With respect to the Developer, this is how not to conduct either an Environmental Impact Assessment or a Screening for Appropriate Assessment – having accepted the presence of the species of concern on the site it is not open to the Developer, applying the precautionary principle, to simply then dismiss the possibility of an impact on an unknown numbers and types of birds on the basis of a series of assumptions favourable to the development and selective and misleading reliance on out-of-context scientific literature.

In relation to the former there is no basis for the assumption that one or more of the four identified species is or could be present on the proposed site . In fact, the species specific information provided by Bird Watch Ireland indicates that long-eared owl (breeds *'usually in a stand of conifers"*), woodcock (*"readily takes to coniferous plantations"*) and merlin (*"are now likely prominently to occur in forested landscapes."*). Equally there is no basis provided for the bald assertion that current levels of disturbance could or do actually prevent the species of concern from nesting on the site of the proposed development. There is, it is submitted, therefore sound scientific basis for the Department's apprehension of the possibility of an impact on these three species and the Developer has done exactly nothing to rebut that possibility.

In relation to Peregrine Falcon the site of the proposed development contains an abundance of appropriate prey species (feral pigeon and other small birds) and the Department was quite correct to apprehend that Peregrine may use the site. The Developer is correct that the site contains no suitable nesting habitat for Peregrine Falcon. However, that observation about nesting sites does not at all address the question raised by the Department. The Board therefore has before it an answer to a question which it did not raise and no answer at all to the apprehended possibility of an impact on peregrine falcon who may use the site for purposes other than nesting. Again, the Developer has simply failed to engage with the concerns raised by the Department. It is quite remarkable that a development of this scale and impact was submitted without any survey data. It is, with respect, absolutely astonishing that the Developer has failed to remedy that lacuna at this stage of the process when it's earlier default was specifically highlighted by the Board.



In relation to the purported scientific evidence relied upon by the Developer, at page 3 of their response the Developer cites a number of scientific papers in support of their submission that recreational users have no significant adverse impact on, in particular, merlin. The FI Response cites a paper by Newton, JE Robinson ED. Wyalden (1981) entitled "Decline of the Merlin in the Peak District" to the effect that report concluded *"that recreational walkers were unlikely to have caused a serious decline in Merlin"*. Notwithstanding the age of that report, the difficulty in relying on a study carried out in dramatically different conditions (heather moorland), the Report did not in fact reach the conclusion contended for. The Report noted that walkers in the heavy moorland of the Peak District were likely to stay to footpaths as, *inter alia,* walking on open heather is an exhausting pursuit. That is not the case in Massy's Wood or the Hellfire Club where walking through the mature forestry off-pathways is easy and frequently undertaken. More to the point the Report noted that (p. 229) *"a well-used footpath running close to a Merlin nest site is therefore particularly likely to cause disturbance"* and (p.232) *"However, there was a negative correlation between latter-day Merlin sites and nearby footpaths, which might suggest a sensitivity to disturbance"* It is, with respect to the Developer, utterly unsatisfactory that even the scant scientific basis they identified has been mis-represented in this fashion. A copy is attached for the attention of the Board.

In the same fashion the Developer identified in their FI document a paper by E.R Meek (1988) on The breeding ecology and decline of the Merlin in Orkney, bird study and states *"Meek suggest little negative impact on Merlin by recreation."* Meek makes no such statement. Recreational users are not mentioned at **any** point in that paper and the only reference to anthropogenic disturbance is to turf-cutting where Meek suggests that there may be some co-relation between that activity and abandonment of nest sites. It is, with respect to the Developer, utterly unsatisfactory that even the scant scientific basis they identified has now **twice** been mis-represented in this fashion. A copy is attached for the attention of the Board.

Lastly the FI response refers to a Report by entitled 'Recreational use of forests and disturbance of wildlife' prepared for the UK Forestry Commission by Marzano & Dandy et al. The Developer quotes this Report as concluding that *"on balance, the available evidence does not indicate significant negative impacts on UK forest birds following "flight" responses to walking including no clear long term or population level impacts".* While this is an accurate quote the Developer leaves out the important point that it is simply a literature review and is not an empirical or peer-reviewed paper in itself. At page v of the review the authors note that while there are a multiplicity of papers generally on the topic they could identify only 5 *"which draw on primary research conducted in UK forests".* References to the dearth of available scientific information, and that that information is concentrated on very particular species, are littered through the Report such as (page 11)(emphasis removed);

*"Within this literature there is once again, however, a very heavy focus upon birdlife (for reviews see Sidaway, 1990; Taylor et al., 2005), which itself focuses substantially upon ground-nesting birds (for a 'systematic review' see Showler et al., 2010) and disturbance by dogs accompanying walkers. Indeed, in their review of the disturbance impacts of dogs, Taylor et al. (2005, p. 56) conclude that 'There is very little relevant research that has focused on the effects of dogs on animal groups other than birds'."*

It is in that context that the Developers statement that the evidence does not support a co-relation between disturbance and long-term negative impact has to be seen. There is no evidence or no sufficient evidence and as even a quick perusal of the Review will substantiate what evidence there is, at best, is ambivalent as to whether such an interaction exists.

Friends submits that the Developer;

1) Should have but did not include bird survey data with the original application,

2) Should have but did not respond to the FI request with appropriate bird survey data,

3) Has now mis-represented two primary papers as to the interaction between recreational disturbance and merlin,

4) Has described as a 'Research Report' what is in fact a literature review carried out for the UK Forestry Commission whose conclusions are tentative and ambivalent.

Friends submits this is an entirely inadequate response to the Board's FI request in relation to the potential impact on avi-fauna. More significantly, the Board is reminded that the Developer did not conduct an Appropriate Assessment on the potential impact from the proposed development. It excluded the possibility of such an impact at screening stage.

The obligation on a developer who adopts this course of action it to **rule out** the possibility of any impact on a European Site at screening stage. If that possibility cannot be ruled out then a full Appropriate Assessment must be carried out. This is identified, *inter alia,* in section 177U of the Planning and Development Act 2000 which reads (in relevant part/emphasis added):

*"(4) The competent authority shall determine that an appropriate assessment … of a proposed development, …* ***is required if it cannot be excluded****, on the basis of objective information, that the … proposed development, individually or in combination with other plans or projects, will have a significant effect on a European site.*

*(5) The competent authority shall determine that an appropriate assessment of … a proposed development,…****is not required if it can be excluded****, on the basis of objective information, that the … proposed development, individually or in combination with other plans or projects, will have a significant effect on a European site."*

It is the Friends respectful submission that the Developer has failed to exclude the possibility of significant effects on Natura 2000 sites or their conservation objectives at screening stage as they have provided no hard survey evidence upon which such a stance could be grounded.

It is Friends case that the Respondent was therefore under an obligation to require the submission of a full Natura Impact Statement. It is Friends case that the Board therefore had no jurisdiction to grant the permission sought on the basis of, *inter alia,* the analysis advanced by Ms Justice Finlay Geoghegan in *Kelly v An Bord Pleanála* 2014 [IEHC] 400.



This raises a second macro issue. As above, at no point has the Developer sought to evince a hard scientific basis for its optimistic assumptions of no significant impact. Equally, and significantly, at no point has the Developer sought to model the potential impact from the anticipated increase in recreational users (whether hikers, mountain bikers or horses or the cumulation of them). The Developer should have employed the precautionary principle, but has failed to, forecast what a three or four fold increase in recreational user in this confined recreational area will have on, *inter alia,* the flora and fauna present on the site. This is true of each and all of the various flora and fauna in relation to which the Department expressed a concern.

**Natura 2000 sites**

The Department expressed a concern that the application had failed to take into consideration the possible impact on surrounding European sites in the immediate vicinity including, Glenasmole valley SAC (site code 001209) circa 1.2 km away, the Wicklow Mountainss SAC (site code 002122) circa 0.6 km away, and the Wicklow Mountains SPA (site code004040) circa 0.9 km away. The Department was of the view that the proposed development could bring greater pressure to bear on these sites as they are close to the Dublin Mountain Way which links or goes close to these 3 sites and which is accessible from the Hell Fire Club. The Board, in its FI Request, echoed that concern and asked for additional information on how the proposed development may impact on those sites via increased visitor numbers.

In response the Developer states simply that the Dublin Mountain Way does not enter the latter two and therefore impacts on their conservation objectives from the anticipated increased visitor numbers would not occur. However, (and as acknowledged by the developer) the DMW goes very close to both and is linked via well-established trails to both Natura 2000 sites (such as at Cruagh car-park where there are trails linking directly to both the DMW and which lead into the Natura 2000 sites). There is therefore a real basis for the Department's belief that those two Natura 2000 sites will come under increased pressure from recreational users as a result of the development and the Developer has simply failed to include any assessment of that pressure.

In relation to Glenasmole Valley SAC the Developer acknowledges by way of response (page 3); *"The Glenasmole Valley SAC, which the Dublin Mountain Way does enter, is protected for rare grassland habitats and petrifying springs which occur on farmland and are not accessible to the public."* With respect to the developer there is no basis for its statement that that conservation objectives occur on farmland and are not accessible to the public. No such statement is recorded in the Site Synopsis or any of the data made publicly available and no source is provided. The Developer cannot simply state as fact a statement for which it appears to have no empirical basis. As above there is therefore a real basis for the Department's belief that this Natura 2000 sites will come under increased pressure from recreational users as a result of the development and the Developer has again simply failed to include any assessment of that pressure.



The Developer has also undertaken a survey of walkers from 3rd to 6th November 2017 from which it extrapolates that the link between Cruagh and Massy's Wood is not currently well-used. Leaving aside the utter inadequacy of a survey carried out over one wet, damp and squally winter weekend with very limited daylight hours and which is entirely un-representative of summer usage this ignores the fundamental point. The reason that the link between Massy's Wood and Cruagh is not significantly used is because Massy's Wood does not currently function as a recreational hub for the DMW and walkers who park at the facilities use it overwhelmingly to walk in Massy's Wood and the Hellfire Club. If the proposed development proceeds it will become the flagship recreational project and location in the Dublin Mountains to which very large numbers of recreational users will be drawn. It is therefore entirely foreseeable that very large numbers of recreational users who do not currently will then seek to access Glenasmole Valley SAC. The Developer has (however inadequately) modelled current recreational usage but has made no attempt to model the alteration in both numbers **and** distribution which the construction of the project will entail.

**Red Squirrels**

Red Squirrels are protected under the 5th Schedule of the Wildlife Act 1976 and the 3rd Schedule of the Bern Convention. Red Squirrels are present in both Massy's Woods and the Hellfire Club. The Developer has very fairly acknowledged that there will be a significant medium term impact on the red squirrels from the proposed development on what they describe as *"an important habitat for Red Squirrels"*. A Red Squirrel Conservation Management Plan has been produced. This candidly acknowledges the same significant impacts and notes that the habitat for red squirrel will be degraded by the removal of mature trees at the site of the current car-park, an increase in traffic leading to increased mortality and the likelihood that an increased food supply from the recreational users will attract grey squirrels who will rapidly out-compete and supplant the native reds.

In response the usual list of mitigation measures, including the presence of an ecologist, the implementation of phased alterations to the forest cover and shooting of grey squirrels is proposed. However, these are simply listed without any assessment of their possible effectiveness or any assessment as to how these specific measures will address or mitigate the specific risks and threats which will be faced by the red-squirrel population at the proposed development site either via construction or the four-fold increase in recreational users which are anticipated. In this regard Friends relies, by analogy (it is a Habitats Directive) rather than an EIA decision), on the decision of the Court of Justice in *Commission v Germany* (Case 142/16) in which the Court held that developers were not entitled to rely on mitigation measures whose efficacy was unknown at the time the consent decision was granted.



The reality is that there will be a serious impact on red squirrels from the proposed development. On the Developers own submission the development will lead to increased mortality and the likelihood of the introduction of grey squirrels to the area which will inevitably lead to the destruction of the reds. As above, there is no assessment of the impact that the **increased** numbers of visitors will have and no appropriate survey data on a multi-day, multi-season, multi-annual basis to assess the number, behaviour and distribution of red-squirrel on the site. Equally there has been no drey count completed or the location of any dreys (beyond the one to be destroyed) identified. A two-day walkabout survey (as referenced in the original application) is a manifestly unacceptable tool with which to assess the potential impacts. Friends of Massy's Wood conducted a two-hour walkabout of the Wood on 5th November 2017 and spotted 18 dreys within 2 hours. Undoubtedly there are many more but, in the absence of any survey data, the Board has absolutely no idea of the population density or distribution of red squirrel and therefore the effect of the proposed development.

Finally, and tellingly, the Department asked that the proposal to clear-fell the area adjacent to the car park will need to be modified in order to protect the red squirrel habitat. However, the Red Squirrel Conservation Management Plan produced by the developer (at paragraph 4.2) simply reiterates that this conifer woodland adjacent to the existing car park will be destroyed.

**Pine marten**

Friends have serious concerns about the lack of adequate and proper response by the Developer to the concerns raised by the Department and the Board. Pine Marten are protected throughout their range for the purposes of Annex V and Article 15 of the Habitats Directive. It is also protected under the Wildlife Act 1976.

The Department in its letter identifies the fact that pine martens are important in helping red squirrel populations to grow (by predating on grey squirrels). They state: *"pine marten conservation in the area would also be an important factor to include in any plan"* and that *"it is not clear why this [the pine marten] was not also made a key ecological receptor (KER), particularly in its likely role in controlling grey squirrels as mentioned above"*.

As with birds and red squirrels **no survey data** was included by the Developer in relation to pine marten and has never provided any explanation to justify this oversight. In its FI response the Developer simply notes that pine martens are (p. 5) *"nocturnal and elusive"* and *"are unlikely to be affected by the project as a result of existing disturbance by people and dogs, which may result in them being habituated to human disturbance or nesting away from the area of the development"*. With the obvious caveat that the Developer is in no position to make any assessment of impact on pine marten from the proposed development as it has no idea where or how many of the species is present on site, the Developer cannot simply state as fact the likelihood of non-disturbance during a year of continuous construction and when the number of recreational users is forecast to more than triple. Significantly, the Developer identifies absolutely no scientific basis for its optimistic assumptions. These assumptions run counter to, *inter alia*, its own earlier statements (EIAR [Vol 1, p96 6.5.4.5.] where it statement states *"the proposed development will result in habitat loss, disturbance and displacement to the fauna that reside within and adjacent to the proposed development."*. Even though the Developer did not deign to survey them, presumably this also includes the pine marten.



While the same Report does record that *"no suitable den or refuge sites were identified within the study area. It is considered that the proposed development will not impact significantly on the species and, therefore, it is not included as a key ecological receptor and no further surveys are required"* this statement is a tautology. There was no survey or any dedicated assessment effort by the Developer and therefore the fact that no den sites were identified is neither surprising nor evidence of the presence or otherwise of pine marten on site.

The only evidence supplied by the Developer in this regard (although it is not clear to what purpose) is that *"pine martens have large territories"*. In fact Dr O'Mahony's paper says that "core ranges were small", are slow breeders with poor survival rates for kits. The same author in the "National Pine Marten Population Assessment" stated that *"there is little or no evidence of any recent expansion from core population areas (18% of land area) on the island of Ireland despite recent increases in forest cover and full legal protection"*. The paper states that *"the pine marten is one of the rarest wildlife species in Ireland and, based on our studies, an evidence-based conservation strategy that promotes a sustainable future for the species needs to be developed"*.

This is exactly the type of information which has not been included by the Developer and it is frankly astonishing that the FI Response was to rely on the results of a bat survey as somehow evidence of an absence of impact on this species.

**Bats**

The Department made it clear in their submission that they do not consider the bat survey supplied by the applicant to be adequate. This survey consisted entirely of one two-hour entry survey and one two-hour exit survey carried out at unknown locations at different days by an unidentified number of surveyors. No survey data was supplied and no actual raw data was included in the EIAR or the FI Response other than the bald statement that bat activity was low.

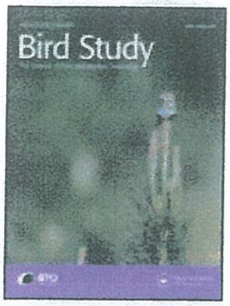
Contrary to the Guidelines cited by the Developer no adequate Bat Surveys were carried out. A copy of the Guidelines are appended. Those Guidelines specifically require tree surveys to be carried out and specify a minimum number of survey visits in respect of structures. This ranges from 1 (low likelihood of roost presence) to 3 (high likelihood of roost presence) and which, in any event, do not provide confidence in relation to a negative assessment for trees for which tree specific surveys are required. That is exactly what should have occurred here. Contrary to the Developer's statement that tree specific reports were not required, the Guidelines make it clear that **only** tree specific reports are adequate when one (as here) is assessing the impact of a proposed development on a potential tree roosts. Equally the Developer has made no effort to remedy what it candidly acknowledges as a deficiency in its own process that (p. 10) *"It is acknowledged that static surveys throughout the site would provide a more detailed picture of use by bats"* on the baffling basis that the mitigation would be the same. This, with respect, entirely ignores the point. A bat survey is designed to place the consent authority in a position to assess whether a development should proceed or not because of, *inter alia*, the impact on bats. It is not a tool simply in order to identify mitigation measures in respect of species which the developer (as with birds, red squirrel and pine marten) simply has no idea of their distribution.

In this regard it is highly significant that all Bat species in Ireland are protected for the purposes of Annex IV of the Habitats Directive and are entitled to strict protection throughout their range. This includes from interference with their breeding, resting and foraging places and disturbance (whether deliberate or not). The Developer in this case has presented no information to the Board which would allow the Board to discharge its obligation of strict protection.

In conclusion Friends of Massy's Wood submit that the grounds for refusing this application are clear and unambiguous. The Applicant has blatantly ignored the requirements of the Department of Culture, Heritage and Gaeltacht requested in their letter dated 25th September 2017.

We trust that the Board will give due consideration to the grounds set out in this submission. Thank you for your kind attention to this matter.

Elizabeth Davidson
On behalf of Friends of Massy's Wood

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# Decline of the Merlin in the Peak District

I. Newton , J. E. Robinson & D. W. Yalden

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Published online: 23 Jun 2009.

# Decline of the Merlin in the Peak District

*by I. Newton, J. E. Robson and D. W. Yalden*

*As a breeding species, the Merlin has almost disappeared from the Peak District. A discussion of causes singles out pesticides as probably the most important factor.*



ALTHOUGH THE MERLIN *Falco columbarius* is regarded as a declining species, both in Britain generally (Parslow 1967) and in the Peak District (Herringshaw and Gosney 1977, Frost 1978), little detailed information has been published on the subject. In part, this reflects the secretive habits of the bird itself, and in part those of ornithologists who have tended, justifiably, to maintain a discrete silence about nests found. In the Peak District (which includes parts of Derbyshire, Staffordshire, Cheshire, West and South Yorkshire, and Greater Manchester), the species is now so rare that information on its former distribution is of little more than historical interest. In this paper, we attempt to assess the extent and causes of this decline, paying particular attention to habitat change, recreational disturbance and organochlorine contamination.

## FORMER STATUS

Personal records, discussions with ornithologists, gamekeepers and former egg-collectors, and an examination of museum egg-collections, yielded information on at least 57 former nesting territories (and in three cases alternative nest sites). These early records spanned the years 1870-1950, a period when land-use and habitat were fairly stable in the Peak District. It is unlikely that this represents anything like a complete picture for the time, but 28 territories in the main area of northern moorland, roughly 381 km², suggests a minimum density of 7.3 pairs/100 km²; 14 territories on 82 km² of the eastern moors suggests a minimum density of 17.1 pairs/100 km², and 11 territories in 85 km² of the southwestern moors suggests 12.9 pairs/100 km². The average 'nearest neighbour' distance for all 60 nest sites was 2.1 km (range 0.6-5.3 km), with most sites in the range 1.2-2.6 km apart. It is, of course, possible that more of the nest sites were alternatives in one territory; equally, the most remote sites might have had nearer neighbours than were known to us. Only in one area, centred on Longshaw (SK 2680), were we certain that all nesting places were known, and here eight pairs used to nest regularly in 32 km², a density of 25 pairs/100 km².

We have little information on occupancy of territories, but two places examined annually between 1869 and 1873 held pairs every year except one (Seebohm 1883). The eight adjacent territories mentioned above were occupied 'every year from 1927 into the 'fifties and were then deserted one by one' (W. Gibbs). Another nesting place near Chesterfield was occupied without break between 1953 (when it was found) and 1958 (when it was last checked). These figures suggest a high degree of occupancy in the years concerned, an impression borne out by comments from old gamekeepers and others, and by Rowan's (1921-22) experience on the North York moors. It seems to have been usual for Merlins to use the same places over long periods of years, often without break.

Newton *et al* (1978) gave densities for two Northumberland areas, which held 45 and 20 known nesting places (including alternatives)/100 km². In three recent years these areas held 13, 7 and 7 nests/100 km², and 10, 3, 10 nests/100 km², densities of the same order as those possible in the Peak District. The greater density of known nesting places in Northumberland need not necessarily have implied a greater breeding population, for apart from the three years of study, there were no data on the proportion of places occupied each year. On the north York moors, Rowan (1921-22) regularly found four pairs in 20 miles², equivalent to about 8 pairs/100 km², and again within the range of Peak District figures.

The 60 former nesting places in the Peak District spanned the altitude range 850-2000 ft, with the mean at 1276 feet (389 metres). Of 45 for which we have a record of the actual nest site, 28 were on the ground among heather and three among bracken, 11 were in disused tree nests of Carrion Crows *Corvus corone* or Magpies *Pica pica*, two alternated between ground and tree, and one was on a small crag. When in old Magpie nests, Merlins usually waited until the top had been lost.

The idea we gained of the former breeding success of Peak District Merlins was probably biassed, because almost all records were of pairs killed by gamekeepers or robbed by egg-collectors. Of 23 clutches preserved in collections, 19 contained 4 eggs, two contained 3 eggs and two contained 5 (mean 4.0). Egg collectors are known to have preferred clutches of 4 or 5, considering those of 3 as less desirable.

## DECLINE

Although the year in which well-used nesting places were abandoned is known in at least seven cases, for most places only the decade could be specified (Table I). Three places were last known to have been used between 1910 and 1920, one in the 1920s, four in the 1930s, four in the 1940s, twenty-five in the 1950s, and seven in the 1960s; only sixteen were still in use in the 1970s, and only 4-5 of these were used in 1978-1980.

Because the above is based on sporadic information supplied by numerous observers, we cannot state the level of occupancy for all those nesting places in every recent year. However, one of us (J. E. R.) endeavoured to check every known nesting place in a large part of the northern Peak District in each of the seasons 1973-1980 (Table II). Of a total of 169 potential nesting attempts, on only nine occasions were territories occupied (that is, Merlins were seen) and in only five of these were nests found. (Three of the latter were successful, producing 3 young in 1977, 2 in 1978, 1 in 1979 respectively.) Signs suggesting that birds had been present early in the season were found at another five places, but with

TABLE I. MERLIN NESTING PLACES IN THE PEAK DISTRICT

| *Decade known to have last been used* | *Access area:* | | *Footpath nearby:* | | *Present vegetation heather:* | | *Formerly heather now lost* ‡ | | *No.* |
|---|---|---|---|---|---|---|---|---|---|
| | *Yes* | *No* | *Yes* | *No* | *Yes* | *No* | *Yes* | *No* | |
| 1910-1919 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 3 |
| 1920-1929 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 1930-1939 | 2 | 2 | 1 | 3 | 1 | 3 | 2 | 2 | 4 |
| 1940-1949 | 2 | 2 | 0 | 4 | 1 | 3 | 3 | 1 | 4 |
| 1950-1959* | 10 | 15 | 10 | 15 | 13 | 12 | 11 | 14 | 25 |
| 1960-1969 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 7 |
| 1970-1979† | 8 | 8 | 2 | 14 | 7 | 9 | 4 | 9 | 16 |
| Totals | 28 | 32 | 17 | 43 | 27 | 33 | 25 | 32 | 60 |

*Includes alternative nest sites in two territories.
† Includes two sites probably still in use in 1979, and alternative nest sites in one territory.
‡ Cannot be scored for all sites, due to partial coverage only of area by Moss (1913).

TABLE II. FINDINGS AT NESTING PLACES CHECKED IN THE NORTHERN PEAK DISTRICT, 1973–1980

| | *Places checked* | *Signs present* | *Birds seen* | *Nests found* |
|---|---|---|---|---|
| 1973 | 19 | 4 | 2 | 0 |
| 1974 | 19 | 2 | 1 | 1 |
| 1975 | 20 | 2 | 1 | 1 |
| 1976 | 20 | 1 | 1 | 0 |
| 1977 | 22 | 2 | 1 | 1 |
| 1978 | 22 | 1 | 1 | 1 |
| 1979 | 22 | 1 | 1 | 1 |
| 1980 | 25 | 1 | 1 | 0 |
| Totals | 169 | 14 | 9 | 5 |

no indication that nesting had occurred. In 1979, in the Peak District as a whole, we knew of two or three occupied territories of which at least one was successful; in 1980 we knew of one or two, but we were uncertain of any nesting success.

As another indication of continued decline through the 1970s, D. Marshall made the following sightings of Merlins during successive winters (September-April) on the moors west of Sheffield: 1974/75 – 5 birds (one/9.8 visits), 1975/76 – 7 birds (one/5.3 visits), 1976/77 – 6 birds (one/6.7 visits), 1977/78 – 3 birds (one/10.7 visits), 1978/79 – 3 birds (one/11.7 visits), 1979/80 – 2 birds (one/19.5 visits). Apart from the first winter, progressively more visits were made for each bird seen. From what is known of Merlin movements, most of these would have been local birds (see later). Of course these observations on their own are insufficient to establish a trend, but they agree with the breeding records on a continuing decline through the 1970s.

## POSSIBLE CAUSES OF DECLINE

*Loss or change of habitat*

In Northumberland, land-use changes destroyed some traditional nesting places of Merlins; these involved the conversion of heather moorland, in one case to plantation forest and in two cases to tightly-grazed sheep pasture (Newton *et al* 1978). In the Peak District, forestry plantations still cover only 6,000 ha (about 10%) of the gritstone areas (Peak Park Planning Board 1974), and are generally confined to lower valleys rather than to the higher ground favoured by Merlins. We have no evidence that any territories in this area have been lost to tree-planting. On the other hand, the conversion of heather to grassy sheepwalk has been marked and widespread in the Peak District. Sheep stocks in the moorland parishes of the region are three times greater now than in the 1930s (Yalden 1972). Moss (1913) studied the vegetation of much of this area, and his maps suggest a total of 171 km$^2$ of moorland dominated by heather *Calluna vulgaris* or bilberry *Vaccinium myrtillus*. Re-survey suggests that there are now only 93 km$^2$ of similar habitat, a net loss of 78 km$^2$ (Anderson and Yalden 1981). The loss was mainly on the lower slopes of the moorland, especially the clough sides, where many former Merlin nest sites were situated. Tall heather provided the favourite type of nest cover (see above), and its loss could have been responsible for the desertion of some areas, especially where trees with stick nests were also lacking.

The habitat surrounding the nest site is also important for foraging and it is possible that loss of heather resulted in a reduction of prey. Merlins feed almost exclusively on small birds of open country, and in two studies Meadow Pipits *Anthus pratensis* contributed about half the total (Newton *et al* 1978, Watson 1979). To explore this possibility further, we compared small bird numbers on heather moor with those on

TABLE III. RELATIVE DENSITIES OF SMALL BIRD TERRITORIES IN DIFFERENT VEGETATION TYPES IN THE PEAK DISTRICT MOORLANDS.

| *Dominant vegetation* | *Number of counts* | *Meadow Pipit: mean no. ± s.d* | *All small birds: mean no. ± s.d.* |
|---|---|---|---|
| Heather *Calluna vulgaris* | 22 | 4.72 ± 2.07 | 6.45 ± 2.50 |
| Mat-grass *Nardus stricta* | 7 | 4.86 ± 1.86 | 5.57 ± 2.30 |
| Wavy hair-grass *Deschampsia flexuosa* | 4 | 1.25 ± 0.5 | 1.75 ± 0.96 |
| Cotton grass *Eriphorum vaginatum* | 5 | 1.20 ± 0.84 | 3.60 ± 0.56 |
| Various (*Molinia*, mixtures, meadow) | 8 | 5.13 ± 2.42 | 8.13 ± 2.53 |
| **Statistical comparisions:** | | | |
| *Calluna v. Nardus* | | t = 0.17, n.s. | t = 0.86, n.s. |
| *Calluna v. Deschampsia* | | t = 13.88, P<0.001 | t = 6.56, P<0.001 |
| *Calluna v. Eriophorum* | | t = 6.07, P<0.001 | t = 4.84, P<0.001 |

NOTES. Counts are for timed line transects of 15 minutes each; 'all small birds' includes all passerines plus Dunlin *Calidris alpina*. The intention was to record territories; pairs were counted as one.



grassland, from line transects during the 1980 breeding season. Counts were timed at 15 minutes each (using a clockwork egg-timer), which corresponded to roughly 1 km of walking. They were spread between different habitats on the same day, and where possible, compared surviving heather moorland with neighbouring grassland areas which were known to have formerly been under heather. Most of the 'lost' heather moorland is now rough grassland dominated by mat grass *Nardus stricta*. From our counts, no clear difference in bird densities was evident between heather and mat grass, either for small birds as a whole or for Meadow Pipits in particular (Table III). The upper slopes of the hills, where heather has been lost, are now covered with overgrazed *Deschampsia flexuosa*, and this grassland had significantly fewer prey than heather; cotton grass *Eriophorum vaginatum* mosses also had fewer prey. Generally, however, it seems unlikely that loss of Merlins could be blamed on a loss of potential prey subsequent to vegetation changes: overall, the *Deschampsia* grasslands comprise only a small part of the vegetation cover, and the *Eriophorum* areas are somewhat less extensive now than they used to be.

If the decline of Merlins in the Peak District is in any way attributable to loss of heather moorland, one might expect to find that a large proportion of the abandoned sites were in areas formerly under heather but now under grass; more importantly, one would expect that most of the nests found in recent years would be in areas still dominated by heather. These points were examined with the help of the vegetation maps mentioned above, taking an arbitrary circle of 1 km radius around each nesting place to represent the home range. Of the 16 places that remained in use into the 1970s, seven were surrounded by 40% or more heather and three by 15 - 35% heather, while six had no heather nearby; also of the 16 sites, five had shown some decline in extent of heather between the two surveys. Of the seven places that were abandoned in the 1960s, five were in home ranges with more than 20% heather, and three of those showed some loss of heather. However, of 25 sites which were abandoned in the 1950s, 23 were in heathery areas and seven showed some loss of heather (but eight could not be scored for loss of heather because Moss' (1913) maps did not cover the areas concerned). Thus, the later occupied nests were, if anything, less often in heather areas than the earlier abandoned sites: eight of 23 post-1960 home ranges were in non-heather areas, compared with two out of 25 ranges in the 1950s.

The possibility remains that some specific nest sites have been lost because their heather cover has gone, but this is hard to evaluate without precise locations for the former sites. Only seven of the 1970s nests and three of the 1960s ones were in heather, while a further six sites, not recently in heather, might previously have been so. Of the 25 nesting places abandoned in the 1950s, 11 are still mainly under heather; 10 of the other 12 might have formerly been in heather which has now been lost. It is therefore possible (since the substantial increase in sheep stocks began in the 1950s) that some Merlins were displaced by changes in vegetation that resulted from sheep grazing. However, the low degree of association between recent Merlin nests and heather strongly suggests that this cannot have been a crucial factor. In addition, some Merlins used to nest among bracken rather than heather, a habit particularly prevalent in the 1930s on the moors to the north of the Peak District (J. Armitage, pers. comm.). Bracken is now widespread in the Peak District on the clough sides, and is readily available as an alternative to heather.



*Recreational disturbance*

Throughout this century, there has been access to numerous public footpaths across the moorland, and some increase in walkers probably occurred as early as the late 1940s. However, since the declaration of the Peak District National Park in 1951, the Park authority has tried to negotiate 'access agreements' with landowners which allow ramblers to wander freely over the moorland. The first of these came into effect in 1955, while another 20 were enacted up to 1965. Many moorland owners have remained suspicious of the disturbance which might be caused to breeding Red Grouse *Lagopus lagopus*, but an investigation by Picozzi (1971) produced no evidence that Red Grouse populations were reduced in access areas. Raptors are supposed to be much less tolerant of human disturbance than some other birds, and the ground-nesting Merlin might be particularly vulnerable. In fact, 12 of the 23 breeding places which were known to have been used after 1960 were in areas subject to access agreements, compared with 16 of the 37 which were not known to have been used after this date. Clearly, access areas, as such, have not been a major factor in the abandonment of nesting places by Merlins.

However, various surveys have shown that, even in access areas, most walkers keep to footpaths (long heather, in particular, is tiring to walk through); Picozzi (1971) found that 95% of walkers in access areas restricted themselves in this way. A well-used footpath running close to a Merlin nest site is therefore particularly likely to cause disturbance. Many footpaths run up the cloughs, and many Merlin nest sites were on the sides of cloughs. Intense disturbance due to other recreational activities could also have affected some sites; rock climbing, in particular, is a popular activity in the Peak District, and some sites were close to favoured crags.

To assess the possible impact of such disturbance, the 60 historical nest sites were scored according to whether a footpath (or other source of obvious disturbance, such as a climbing cliff) runs close enough to have endangered the site. For only 17 sites was this a possible cause of desertion, and one must qualify this further. Firstly, these 17 sites have prominent footpaths nearby now, but recreational disturbance is largely a feature of the 1970s. For example, visitors to the Edale Information Centre, who would mostly be hikers, were only 9,000 in 1965 but had increased to 63,000 in 1977 (Brunt 1979; Figure 1). We cannot say whether the footpaths would have caused enough disturbance to precipitate desertion at the time it happened. Secondly, our judgement of whether a nest

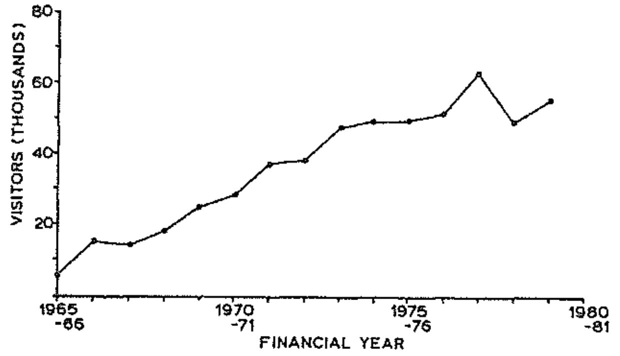


Figure 1. Visitors to the Edale Information Centre, Peak National Park, for the financial years 1965–66 to 1979–80.

Edale has no major tourist attractions addition to the scenery and hiking opportunities; the number of visitors to the centre therefore gives a better indication of recreational pressures in the Peak Park than do those to other information centres, such as Castleton or Bakewell.

site might have been under threat from a footpath was perhaps pessimistic; Merlins tend to sit tight when hikers pass up the opposite side of the clough to that having the nest, but fly off if approached on the near side.

Against these reservations, however, one salient feature must be noted. Of the 17 sites which might have been threatened by disturbance, only five are known to have been used after 1960. Of the 16 sites which were used after 1970, 14 are remote from footpaths, and therefore relatively undisturbed. This may indicate that, as the Merlin has become scarcer, it has avoided the most disturbed areas. Newton *et al* (1978) noted that two of their five 'lost' sites had suffered from disturbance.

*Organochlorine pesticides*

The timing of the decline of Merlins in the Peak District, with over half of the losses attributed to the late 1950s, coincided with that shown nationally by Sparrowhawks *Accipiter nisus* and Peregrines *Falco peregrinus*, associated with the use of organochlorine pesticides. DDT or its metabolites caused eggshell thinning; while dieldrin and other pesticides poisoned adults (Ratcliffe 1970, Newton 1979). Substantial shell-thinning and breeding failures have been documented in British Merlins (Ratcliffe 1970, Newton 1973), and organochlorine compounds have been found in all the eggs from 65 clutches that have been analysed (Newton *et al*, in press). It is instructive to compare the data from Peak District clutches with those from the rest of the country. DDT came into wide use in 1947 and we have examined four clutches collected in the Peak District after that date for shell-thickness, and two for organochlorine content (Table IV). The four clutches showed an average of 21% shell-thinning (compared with 17% in the country as a whole in 1971-1979), and the two with 29% and 30% thinning had the most fragile shells yet recorded from British Merlins. The two that were analysed chemically had relatively high levels of DDE (from DDT) and HEOD (from aldrin and dieldrin), and one had the most PCB (industrial polychlorinated biphenyls) recorded from a Merlin (412 ppm in lipid, compared to a geometric mean of 92 ppm in 65 clutches from Britain as a whole). Both these last clutches failed completely. With the species almost extinct in the Peak District, there is little hope of analysing more eggs in the immediate future, but existing

TABLE IV. SHELL-THINNING AND ORGANOCHLORINE LEVELS IN MERLIN EGGS FROM THE PEAK DISTRICT

| *Year* | *Nearest village* | *Shell index* | *% thinning* | *DDE* | *PCB* | *HEOD* |
|---|---|---|---|---|---|---|
| 1953 | Holymoorside | 1.17 | 7 | — | — | — |
| 1969 | Ripponden | 0.89 | 29 | — | — | — |
| 1974 | Derwent | 0.88 | 30 | 220 | 131 | 5 |
| 1975 | Meltham | 1.04 | 17 | 109 | 412 | 15 |
| 1971-1979 | *Mean values for 65 Merlin clutches from other parts of Britain | 1.05 | 17 | 118 | 92 | 8 |
| 1975-1977 | *Mean values for 5 Sparrowhawk clutches from Peak District | 1.18 | 17 | 86 | 138 | 16 |

NOTES. Peak District Merlin data are compared with mean values for Merlins in Britain as a whole, and for Peak District Sparrowhawks. Each clutch is represented once only by mean values; residues in ppm in lipid.

Shell index is a measure of thickness calculated by the formula of Ratcliffe (1970): shell weight (mg)/length x breadth (mm).

% thinning was calculated for Merlin from a shell index of 1.26, the mean of 24 museum clutches collected in the Peak District before 1947; for Sparrowhawk, calculated from a shell index of 1.42, the national average before 1947.

*For organochlorine levels, these are geometric means.



findings leave no doubt that the local Merlins have been hard hit by organochlorine contamination.

The use of organochlorine pesticides is unlikely to have been high in the Peak District itself (sheep dips contained dieldrin in the past), but wind may have carried unusual amounts of PCBs to the moorlands from the extensive industrial areas on either side. It was in their British wintering areas, however, that Merlins and their prey were most likely to have picked up the high pesticide residues. Peak District moorlands are largely deserted by small birds in winter; the abundant Meadow Pipits, as well as Skylarks *Alauda arvensis* and Twite *Carduelis flavirostris*, move to lower ground, while the small waders (*Calidris alpina, Actitis hypoleucos*) and Wheatears *Oenanthe oenanthe* move further afield (abroad). A few Merlins can be seen in the Peak District, on the lower eastern moors (see above), where presumably they prey on flocks of finches, buntings and thrushes on adjoining farmland. But most Merlins move to lower ground, and there have been five relevant recoveries of birds born in the district, all found on farmland within 25 km of the moors: near Marple, Macclesfield, Barnsley, Alfreton and Glossop respectively. By analogy with findings from other parts of Britain, a few Peak District Merlins would be expected to move further afield, reaching the estuaries to the east and west, and possibly south as far as France (Mead 1973, Newton *et al* 1978). In view of the recent mass mortality of waders on the Mersey estuary (Osborn 1981), we cannot exclude estuarine pollution as possibly contributing to the decline of Peak District Merlins.

*Other influences*

Some might argue that, in a grouse-shooting area, direct persecution of Merlins by gamekeepers is likely to have been a major cause of decline. Certainly, Merlins were killed by gamekeepers in the Peak District (see above) and we are aware of a few cases post-war, including two birds in 1980 (one of which was subsequently obtained for examination). However, the most notable point about this persecution is that, despite the persistent efforts of pre-1940 gamekeepers, the Merlins survived their attentions, as well as those of egg-collectors, in good numbers. Seebohm (1883) describes in two Peak District localities how pairs were shot year after year and not a single young was raised, yet every year the same territories were re-occupied by new recruits, and Rowan (1921-22) made similar observations in North Yorkshire. The number of moorland gamekeepers in the Peak District has in fact declined from 49 in 1930s to 24 in the 1970s (Yalden 1972, J. Perkins pers. comm.), so that direct persecution should have declined substantially, even if the Protection of Birds Acts have had no effect on gamekeeper behaviour. Egg-collecting has also declined substantially since these Acts were passed. It is possible that collective direct persecution, by gamekeepers, egg-collectors and falconers, holds down the present remnant Merlin population in the Peak District, but it does not seem possible that it reduced the population so markedly in the first place. Any successful egg-collector or falconer is unlikely, at present, to waste his time in the Peak District.



## DISCUSSION

The early records are sufficient to establish that Merlins once bred much more numerously in the Peak District then in recent years, but (with two exceptions) they are insufficient to establish the degree of stability in numbers. Now, this population is very close to extinction. In the main northern and eastern moors only one of the former 40 known sites was occupied at the end of the 1970s, and even that was vacant in 1980. Elsewhere, perhaps one or two pairs were still breeding in these years.

It is clear that the major decline occurred in the 1950s when nearly half the known nesting haunts were deserted. While there has been a substantial loss of heather moorland in the Peak District, the habitats chosen by the remaining Merlins do not support the view that this was a major factor in the decline. Likewise, the negotiation of access agreements between moorland owners and the Peak Park Planning Board has not produced a negative correlation between access areas and Merlins. However, there was a negative correlation between latter-day Merlin sites and nearby footpaths, which might suggest a sensitivity to disturbance. Since the enormous increase in outdoor recreation in the Peak District occurred mainly during the 1970s, it is unlikely to have accounted for the sharp decline in Merlins during the 1950s. It could, perhaps, delay or prevent recolonisation in future, but given the tendencies of walkers to follow well-known footpaths and to walk (where possible) along ridges rather than in cloughs, there should be sufficient undisturbed sites for numbers cf Merlins to breed successfully.

The main part of the decline in the Merlin closely parallels those in the Sparrowhawk and Peregrine, which were undoubtedly due to organochlorine poisoning. The facts that (like them) the Merlin is a bird-predator, that a decline due to pesticides has been documented for North American Merlins, and that exceptionally high levels of organochlorines and shell-thinning were found in the Peak District Merlin eggs, all strongly support the notion that this was the major cause. The Peak District is a tongue of moorland extending south between major industrial areas toward the agricultural Midlands. Merlins breeding here would be more likely than those further north to encounter organochlorine in their prey, either from agricultural or industrial products—if not on their breeding grounds, then certainly in winter. The Peak District Merlin population has declined much more severely than those further north in Britain, which again parallels the Sparrowhawk and Peregrine.

Hence there is little difficulty in accounting for the decline in terms of organochlorine compounds. The main problem is why the species has remained at such a low level in the Peak District, when organochlorine use has been reduced nationally, when Merlins in some other regions have partly recovered in numbers (see Newton *et al* 1978 for Northumberland), and when Sparrowhawks (which also declined to near-extinction in the Peak District) have made a come-back. The two recent Merlin eggs showed more organochlorine and shell-thinning than Sparrowhawk eggs from the same vicinity in the same years, so it is likely that the Merlins and/or their prey (unlike the Sparrowhawks and/or their prey) are migrating out of the Peak District to winter in more contaminated regions. A difference in wintering behaviour between the two species is evident from observation and ringing recoveries. Also, once the Merlin population reached the levels observed in the 1970s, any human persecution or other pressure would have sufficed to prevent recovery. Possibly the decline in gamekeeper numbers, while of direct benefit to Merlins, has allowed an upsurge in the numbers of foxes and other predators of ground nests, which could further have hindered a Merlin recovery.

Since Brown (1976) was not convinced by the evidence that pesticides had precipitated the national decline in the Merlin population, some reconciliation of his views with the conclusion reached here seems necessary. He drew attention to the fact that mean clutch size and mean brood size were no lower in the post-1962 samples than in pre-1962 samples of BTO nest record cards. However, organochlorine use was reduced steadily through the 1960s, and not suddenly from 1962. Moreover clutch-size is not one of the parameters affected by these chemicals (Newton and Bogan 1978), which usually cause complete breeding failure. Of 13 Merlin nests reported by Newton (1973) which suffered egg breakage or depletion of the clutch, nine failed completely and only four showed partial failure. We would argue, then, that Brown's (1976) assessment of breeding success is not an appropriate way to establish reproductive failure of the type caused by pesticide poisoning. On the contrary, the pattern of abandoned territories and low breeding success of the pairs which did hold territories in the Peak District, coupled with the direct evidence from chemical analyses of eggs, is exactly the evidence one would expect in a raptor population suffering from pesticides.

The success of Merlin pairs found in the Peak District during the 1970s was so poor that it could not by itself lead to population increase. Moreover, the area lies at the southern end of the Pennine chain and thus has only one likely avenue for recolonisation, the second nearest population being 100 km away in north Wales. As the breeding of these neighbouring populations is also reduced to some extent by organochlorine contamination (to judge from eggs examined in recent years) this might further slow any recolonisation. Hence, for some years to come, Merlins in the Peak District are likely to remain low in numbers. If they do in time manage to recover from the organochlorine problem, they might never reach their former numbers because of the enormous degree of human disturbance which now pervades large parts of the area. Only time will tell.

In this paper, we have tried to find which, of the several possible causes considered, is likely to have been most important in causing population decline. Of course, we cannot rule out the possibility that other factors, as yet unappreciated, have been involved.

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## SUMMARY

Until the 1950s Merlins nested quite commonly in the Peak District, but by the late 1970s they had declined—probably by more than 90%—to an extremely low level. In 1980 we knew of only one or two pairs. The main part of the decline coincided with more widespread reductions in Merlin, Peregrine and Sparrowhawk populations, associated with organochlorine contamination. In four clutches from the Peak District, shell-thinning was marked (up to 30%), and the two that were analysed contained large residues of organochlorines (one had the most PCB recorded in a British Merlin egg).

The continued failure to recover (in contrast to Merlins in some other areas) is attributed primarily to a continuing organochlorine problem, probably stemming from the region where the Peak District Merlins (or their prey) overwinter. In this respect Merlins differ from Sparrowhawks, which winter locally, feed mainly on resident prey, and have made some recovery since they declined in the 1950s. With the low Merlin numbers of recent years, any human persecution is also likely to prevent recovery, and one pair in 1980 was found shot. Nowadays there is much less land under heather, and far more people visit the Peak District, than when Merlins last bred commonly. Apparently these changes did not cause the decline, but disturbance from human presence may prevent Merlins from achieving their former numbers should the birds recover from the organochlorine problem.




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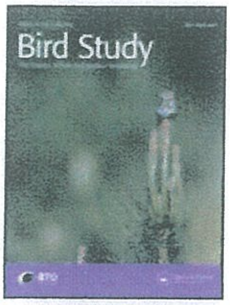


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# The breeding ecology and decline of the Merlin Falco columbarius in Orkney

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# The breeding ecology and decline of the Merlin *Falco columbarius* in Orkney

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*The Merlin population in Orkney has undergone a marked decline during the 1980s. Site occupancy fell from 42% to 14% between 1981 and 86, while mean breeding success fell from 48% during 1975–81 to 29% during 1982–86. Mean brood size of successful nests declined from 3.3 during 1975–80 to 2.5 during 1981–87. Most breeding failures occurred during incubation. Loss and degradation of habitat, disturbance, weather, predation, organo-chlorine contamination and mercury contamination were examined as possible causes.*



The population of the Merlin *Falco columbarius* in Britain is now thought to be 550–650 pairs.[1] It is the only regularly breeding diurnal raptor whose numbers were considered by Newton[2] to be declining in 1984, although the Hen Harrier population is now also causing concern (C.J. Bibby, pers. comm.). Continuing pesticide contamination, the destruction of nesting and feeding areas by the spread of forestry, degradation of prime habitat by moorland reclamation and overgrazing, heavy predation of ground nests by mammalian predators and thefts of eggs and chicks by man have all been suggested as possible contributors to the Merlin's precarious status.[1, 3, 4, 5] In the Orkney Islands, where neither forestry nor mammalian predation appeared to be a threat, it was thought that a study might throw further light on the problem. A detailed survey began in 1981 just before a marked decline became apparent in the numbers and breeding success of the species in the islands.

## HISTORICAL BACKGROUND

Dunn[6] described the Merlin as being more numerous in Orkney than Shetland, while Baikie and Heddle[7] said that it was 'very common. . . chiefly in the hills, but also in cliffs'. Spence[8] also noted that, as well as breeding 'on the slopes of hills', Merlins also nested 'on the grassy crags along the shore' in the parish of Orphir. Although Buckley and Harvie-Brown[9] indicated that it had declined during the preceding 40 years, Omond[10] suggested that it was 'one of the commonest of our hawks' and Lack[11] stated that no decline was occurring in the early 1940s. The first attempt to estimate the breeding population was made by Balfour[12] who considered that there were perhaps 25 pairs during 1955–60, but that a 'slight decrease' had taken place thereafter. The Mainland, Hoy and Rousay are mentioned throughout the literature as the main breeding islands, and it is the West Mainland which appears always to have been the species' stronghold. Balfour's manuscript notes suggest that 13–15 pairs were to be found in this area with 10–12 pairs elsewhere. Against this background, J. Watson surveyed 182 km$^2$ of West Mainland moorland in 1974 and found 13 territories, 6–8 (46–61%) rearing young (I. Newton, pers. comm.). This suggests that there had been little change since Balfour's records.

From 1975, during the course of his Hen Harrier studies, N. Picozzi began to locate and record the success of Merlin nests in the West Mainland. The number of sites checked each year grew as his knowledge of the area increased. Table 1 summarizes his data for 1975–80. The period 1977–80 can be seen as one of stability since Watson's 1974 survey. Breeding success appears to have been rather variable

Table 1. Site occupancy and breeding success of Merlins in the West Mainland, Orkney, 1975–80

| | *1975* | *1976* | *1977* | *1978* | *1979* | *1980* |
|---|---|---|---|---|---|---|
| Sites checked | 5 | 8 | 16 | 16 | 18 | 23 |
| Sites occupied | 5 | 7 | 15 | 14 | 16 | 18 |
| Nests found | 4 | 5 | 12 | 10 | 7 | 11 |
| Pairs successful (%) | 3(60) | 4(57) | 9–10(60–67) | 7(50) | 3(19) | 9(50) |
| Young reared | 9 | 14+ | 29+ | 23 | 9 | 28 |
| Mean brood size | 3.0 ($n$ = 3) | 3.7 ($n$ = 3) | 3.4 ($n$ = 8) | 3.3 ($n$ = 7) | 3.0 ($n$ = 3) | 3.1 ($n$ = 9) |

but the species' poor performance in 1979 was attributed to a very wet summer (N. Picozzi, pers. comm.)

### Habitat and land-use

The rearing of beef cattle is the mainstay of the Orkney economy, and the majority of the rolling hills of the Mainland have been ploughed and re-seeded with grass for pasture or fodder. This reclamation process has affected only the coastal perimeter of Rousay and very little of Hoy, which is underlain by more resistant strata and has a much more rugged topography.

For most of this century, the Orkney moors have been only lightly grazed. During the early 1980s, however, economic pressures and agricultural policy encouraged farmers to increase sheep flocks, and parts of the moors became subject to heavy grazing to the detriment of the semi-natural vegetation. For centuries the Orkney moors have been cut over for peat as a domestic fuel. Such peat-cutting is not usually detrimental to the habitat, the top turf being laid down behind the working bank. In fact, the long Heather *Calluna vulgaris* growth on abandoned banks often provides nest sites for Merlins and other species. However, the large numbers of people on the hills in May and June might create disturbance.

## THE PRESENT STUDY

### Methods

The present study began in 1981. N. Picozzi made available his knowledge of breeding sites in Orkney and further information was obtained from the maps and notes of the late E. Balfour. An attempt was made to visit all known territories at least twice between April and early June each year to check for occupancy. Subsequent visits were made to sites with active nests to record breeding success. All prey items found during these visits were recorded, but to avoid excessive disturbance a thorough search for prey remains was not made until after the young had fledged.

## RESULTS

### Site descriptions

All Merlin nests in Orkney during 1981–87 were in moorland dominated by heather. No nests were in trees (which are scarce in Orkney) and none was found on coastal cliffs. Only twice were the old stick nests of Hooded Crows *Corvus corone* (which in Orkney commonly nest on the ground) used by Merlins. This is in contrast to the situation in Shetland where such nests are used frequently.[13] Both of these stick nests were on the sides of ravines. All other nests were on the ground on slopes varying from very steep to almost flat, and in heather varying from 7 cm to 50 cm in height. Nest sites ranged in altitude from 30 m to 160 m and, in aspect, around all points of the compass. The only features common to all nests were that they were on the ground and in heather.

### Site occupancy

A site was defined as 'occupied' if a nest was found, or if one or both members of the pair had spent a considerable time at the site as evidenced by the presence of more than just one or two pellets or kills that may have been left by a passing bird or a visiting adult from another site. Table 2 gives details of site occupancy and

**Table 2.** Merlin breeding data, Orkney, 1981–1987

| | *1981* | *1982* | *1983* | *1984* | *1985* | *1986* | *1987* |
|---|---|---|---|---|---|---|---|
| Sites checked | 36 | 43 | 44 | 44 | 43 | 43 | 44 |
| Sites occupied (%) | 15(42) | 12(28) | 11(25) | 6(14) | 6(14) | 6(14) | 8(18) |
| Nests found | 15 | 12 | 11 | 5 | 5 | 5 | 8 |
| Successful pairs (%) | 8(53) | 3(25) | 5(45) | 2(33) | 2(33) | 0(0) | 7(88) |
| Mean clutch size | 4.1 (*n* = 11) | 3.9 (*n* = 8) | 3.9 (*n* = 10) | 3.2 (*n* = 5) | 4.4 (*n* = 5) | 3.6 (*n* = 5) | 3.7 (*n* = 7) |
| % Eggs hatched* | 51 | 23+ | 38 | 38 | 32 | 6+ | 73 |
| Young reared | 21 | 7 | 15 | 6 | 7 | 0 | 21 |
| Young reared per nest | 1.4 | 0.6 | 1.4 | 1.2 | 1.4 | 0 | 2.6 |
| Young reared per successful nest | 2.6 | 2.3 | 3.0 | 3.0 | 3.5 | 0 | 3.0 |
| Failure at egg stage (%) | 4(31) | 6(60) | 6(55) | 3(60) | 3(60) | 4(80) | 1(13) |
| Failure at chick stage (%) | 1(8) | 1(10) | 0(0) | 0(0) | 0(0) | 1(20) | 0(0) |

*In nests found at egg stage.



other breeding data in Orkney as a whole, while Table 3 gives these data for the West Mainland alone in order to facilitate comparison with Picozzi's earlier findings. Thus, in the West Mainland, there was a reduction in the number of occupied sites from at least 18 in 1980 to only 4 in 1984–86, and 5 in 1987. Site occupancy declined from 48% to 14% during 1981–84. The apparent 78% occupancy in 1980 may be an overestimate as some little-used sites were not checked that year. In Orkney as a whole, the number of sites declined from 15 in 1981 to 6 in 1986 with occupancy falling from 42% to 14% with a slight increase to 18% in 1987.

**Breeding success**

Tables 2 and 3 give details of breeding success and the stages at which nests failed. A re-lay which occurred at a West Mainland site in 1985 is not taken into account in these tables; this clutch of 3 failed at the incubation stage as did the first clutch.

Breeding success, measured as the proportion of pairs rearing at least one chick, varied from 0%–45% (mean 29%) during 1982–86. The equivalent figures in the West Mainland were 0%–50% (mean 21%). The mean brood size of successful nests in Orkney during 1981–87 was 2.5, but in the West Mainland alone was

**Table 3.** Merlin breeding data, West Mainland, Orkney, 1981–1987

| | *1981* | *1982* | *1983* | *1984* | *1985* | *1986* | *1987* |
|---|---|---|---|---|---|---|---|
| Sites checked | 27 | 28 | 29 | 29 | 29 | 29 | 29 |
| Sites occupied (%) | 13(48) | 10(36) | 7(24) | 4(14) | 4(14) | 4(14) | 5(17) |
| Nests found | 13 | 10 | 7 | 3 | 3 | 4 | 5 |
| Successful pairs (%) | 6(46) | 1(10) | 3(43) | 0(0) | 2(50) | 0(0) | 4(80) |
| Mean clutch size | 4.1 (*n* = 11) | 3.9 (*n* = 7) | 4.3 (*n* = 6) | 3.0 (*n* = 3) | 4.3 (*n* = 3) | 3.5 (*n* = 4) | 3.4 (*n* = 5) |
| % Eggs hatched* | 51 | 11+ | 35 | 0 | 88 | 0 | 71 |
| Young reared | 17 | 2 | 9 | 0 | 7 | 0 | 11 |
| Young reared per nest | 1.3 | 0.2 | 1.3 | 0 | 2.3 | 0 | 2.2 |
| Young reared per successful nest | 2.8 | 2.0 | 3.0 | – | 3.5 | – | 2.8 |
| Failure at egg stage (%) | 4(36) | 6(75) | 4(57) | 3(100) | 1(33) | 4(100) | 1(20) |
| Failure at chick stage (%) | 1(0) | 1(13) | 0(0) | 0(0) | 0(0) | 0(0) | 0(0) |

*In nests found at egg stage.

Table 4. Types of failure during incubation in nests of Merlins in Orkney, 1981–1987

| | *1981* | *1982* | *1983* | *1984* | *1985* | *1986* | *1987* | *Total* (%) |
|---|---|---|---|---|---|---|---|---|
| No. of failures during incubation | 4 | 6 | 6 | 3 | 3(+1)* | 4 | 1 | 28 |
| Examples of depletion resulting in failure | 0 | 2 | 2 | 1 | 0 | 2 | 0 | 7(25) |
| Shell fragments in nest: | | | | | | | | |
| —small | 1 | 3 | 0 | 0 | 3(+1)* | 0 | 0 | 8(29) |
| —large | 1 | 0 | 2 | 1 | 0 | 1 | 1 | 6(21) |
| Nest empty | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 3(11) |
| Desertion (no depletion) | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 4(14) |

*+1 indicates a re-lay.

2.0. This compares with 3.3 in the West Mainland during 1975–80, and 3.3 ($n$ = 153) in Northumberland during 1974–83.[4] In 1987, although occupancy remained low at 18%, breeding success was much improved to 88% (17% and 80%, respectively, in the West Mainland).

The main stage at which breeding failure occurred in Orkney in the present study was during incubation. Forty-eight per cent of all nests failed at this stage (56% in the West Mainland). In 7 (25%) nests failing at this stage, clutch depletion was observed (Table 4). Depletion was also suspected at a further 8 (29%) nests (see Discussion). Clutch depletion also occurred in 7 (29%) of successful nests found at the egg stage (Table 5). Thus, of 52 nests found with contents, at least 22 (42%) showed signs of clutch depletion and/or breakage.

Only 5% of nests failed at the chick stage, only 3 nests being involved. In one case no trace of the chicks remained in the nest and although natural predation was possible, human interference may have occurred. In the 2 other cases, the chicks had been eaten by a mammalian predator which, in Orkney, can only have been Feral Cat *Felis catus*, Dog *Canis familiaris* or Otter *Lutra lutra*.

**Pesticide analyses**

The geometric mean (and the range within 1 geometric standard error) for DDE in 8 Orkney Merlin eggs during 1983–87 was 67.60 p.p.m. (54.20–84.12), for PCBs 23.59 p.p.m. (9.83–57.92) and for HEOD 2.55 p.p.m. (1.16–5.62) (Table 6). The arithmetic mean shell index for eggs during 1982–86 was 1.08 ($n$ = 10). These are compared with other British data for Merlin egg analyses during 1971–80, and for shell indices (in four time periods) in the Discussion.

Levels of mercury in the 8 analysed eggs were well above those for most of Britain. The geometric mean was 5.75 p.p.m. (5.20–6.36)

Table 5. Clutch and brood depletion, and infertile eggs in successful Merlin nests in Orkney, 1981–87

| | *1981* | *1982* | *1983* | *1984* | *1985* | *1986* | *1987* | *Total* (%) |
|---|---|---|---|---|---|---|---|---|
| Successful nests found with eggs | 7 | 2 | 5 | 2 | 2 | 0 | ·6 | 24 |
| Clutches depleted(%) | 2 | 0 | 2[1] | 1 | 0 | — | 2[1] | 7(29) |
| Eggs remaining unhatched and undamaged | 2[1] | 0 | 1[1] | 0 | 1 | — | 0 | 4(17) |
| ?Egg/chick lost | 1 | 1[1] | 2 | 0 | 0 | — | 2[1] | 6(25) |
| Chick lost | 1[1] | 2[1] | 0 | 0 | 0 | — | 1 | 4(17) |

[] indicates instances of both in same nest.

**Table 6.** Shell indices, organo-chlorine and mercury levels in Merlin eggs, Orkney, 1982–87

| | *Shell index* | *HEOD* | *DDE p.p.m. in lipid* | *PCB* | *Mercury p.p.m. dry wt* |
|---|---|---|---|---|---|
| 1982 | 1.07 | | | | |
| | 1.23 | | | | |
| | 1.00 | | | | |
| | 0.89 | | | | |
| 1983 | 1.19 | 5.85 | 77.16 | 32.03 | 5.02 |
| | 0.98 | 0.88 | 32.40 | 43.78 | 9.28 |
| | 0.93 | 33.43 | 153.82 | 57.79 | 4.32 |
| | 1.18 | 9.43 | 46.63 | 78.17 | 5.58 |
| 1984 | | 6.23 | 93.77 | 140.19 | 5.96 |
| 1985 | | 0.85 | 57.91 | 28.25 | 7.02 |
| 1986 | 1.22 | | | | |
| | 1.09 | n.d. | 41.51 | n.d. | 6.70 |
| 1987 | | 8.32 | 197.23 | 76.55 | 3.81 |
| Arithmetic mean | 1.08 | 8.12 | 87.55 | 57.10 | 5.96 |
| Geometric mean | | 2.55 | 67.60 | 23.59 | 5.75 |
| (within 1 geometric s.e.) | | (1.16–5.62) | (54.20–84.12) | (9.83–57.92) | (5.20–6.36) |

n.d. = not detected; s.e. = standard error; each egg analysed was from a different clutch.

compared with a national average of about 2 p.p.m.[14] The Orkney levels were, however, similar to those in Shetland.

### Breeding season prey

In Orkney, Merlins pluck their prey on a fence-post, a tussock of vegetation or often on flat ground. Prey remains are thus more difficult to locate than elsewhere in Britain. Table 7 details the prey remains found at all Orkney sites during 1981–87. The majority were found early in the study, the decline of the population and its reduced breeding success resulting in fewer items in later years.

In numerical terms, three prey species were of outstanding importance. Meadow Pipit, Skylark and House Sparrow together made up over 77% of the items recorded. Amongst the other species, only Wheatear (6.3%) could be considered to be of more than casual occurrence in the diet. When the data were expressed in terms of weight, Meadow Pipit (25.5%) again was the most important item but Skylark (24.8%) was a close second. To a certain extent, however, the Skylark figures are biased by the large number (49) found at one site in 1981. House Sparrow (17.0%) ranked third by weight but Wheatear was equalled by Fieldfare (both 5.6%), the latter usually found in the pre-laying period. Starlings (4.5%) are usually found late in the season.

In the latter part of each breeding season, newly fledged juvenile birds began to appear amongst the prey, and there were also several examples of nestlings of Meadow Pipit and one of Wheatear. One particular Merlin, in 1981, specialized in newly hatched Lapwing chicks, 8 pairs of legs being found on the plucking post. However, nestlings and chicks comprised only 3% of all prey items.

### Movements

There are 43 ringing recoveries relating to Merlins in Orkney. The data suggest the same pattern of movement as outlined for the British population as a whole.[15, 16] There is no evidence of Orkney-bred birds leaving the islands in winters subsequent to their first, but evidence that they remain is restricted to just 3 recoveries. Nestlings were subsequently found as breeding females a relatively short distance from their natal sites, but evidence that the Orkney population is not entirely closed is provided by the breeding in the islands of one female ringed as a chick in Shetland.

## DISCUSSION

The breeding population of Merlins in Orkney has undergone a sharp decline in recent years. By 1986, only 6 sites were occupied, 5 pairs nested and no young were reared. The West

Table 7. Breeding season prey of Merlins in Orkney, 1981–87

| *Species* | *Number of items* | *% by no.* | *% by wt* |
|---|---|---|---|
| Red Grouse *Lagopus lagopus* | 4* | 0.5 | 1.6 |
| Ringed Plover *Charadrius hiaticula* | 1 | 0.1 | 0.3 |
| Lapwing *Vanellus vanellus* | 10* | 1.2 | 0.8 |
| Dunlin *Calidris alpina* | 2 | 0.2 | 0.4 |
| Snipe *Gallinago gallinago* | 5 | 0.6 | 2.1 |
| Woodcock *Scolopax rusticola* | 1 | 0.1 | 1.0 |
| Redshank *Tringa totanus* | 1 | 0.1 | 0.6 |
| Wader (sp?) *Scolopacidae* | 1 | 0.1 | 0.4 |
| Rock Dove *Columba livia* | 2 | 0.2 | 2.3 |
| Skylark *Alauda arvensis* | 173 | 20.5 | 24.8 |
| Swallow *Hirundo rustica* | 1 | 0.1 | 0.1 |
| Meadow Pipit *Anthus pratensis* | 329 | 38.9 | 25.5 |
| Pied Wagtail *Motacilla alba* | 11 | 1.3 | 0.9 |
| Wren *Troglodytes troglodytes* | 4 | 0.5 | 0.2 |
| Dunnock *Prunella modularis* | 1 | 0.1 | 0.1 |
| Stonechat *Saxicola torquata* | 1 | 0.1 | 0.1 |
| Wheatear *Oenanthe oenanthe* | 53 | 6.3 | 5.6 |
| Blackbird *Turdus merula* | 2 | 0.2 | 0.7 |
| Fieldfare *Turdus pilaris* | 13 | 1.5 | 5.6 |
| Redwing *Turdus iliacus* | 4 | 0.5 | 1.0 |
| Mistle Thrush *Turdus viscivorus* | 1 | 0.1 | 0.5 |
| Garden Warbler *Sylvia borin* | 1 | 0.1 | 0.1 |
| Starling *Sturnus vulgaris* | 15 | 1.8 | 4.5 |
| House Sparrow *Passer domesticus* | 151 | 17.9 | 17.0 |
| Chaffinch *Fringilla coelebs* | 3 | 0.4 | 0.3 |
| Brambling *Fringilla montifringilla* | 1 | 0.1 | 0.1 |
| Siskin *Carduelis spinus* | 1 | 0.1 | 0.1 |
| Linnet *Carduelis cannabina* | 14 | 1.7 | 1.0 |
| Twite *Carduelis flavirostris* | 9 | 1.1 | 0.6 |
| Linnet/Twite *Carduelis cannabina/flavirostris* | 4 | 0.5 | 0.3 |
| Common Crossbill *Loxia curvirostra* | 1 | 0.1 | 0.1 |
| Snow Bunting *Plectrophenax nivalis* | 4 | 0.5 | 0.5 |
| Reed Bunting *Emberiza schoeniclus* | 8 | 0.9 | 0.6 |
| Orkney Vole *Microtus arvalis* | 1 | 0.1 | 0.3 |
| Northern Eggar *Lasiocampa quercus* | 3 | 0.4 | 0.0 |
| Emperor Moth *Saturnia pavonia* | 18 | 2.1 | 0.2 |
| Ground Beetle *Carabidae* | 1 | 0.1 | 0.0 |
| | $n = 845$ | | |

* Chicks/small juvs; weight data from Ratcliffe (1980).[25]

Mainland has always been the species' stronghold in the islands and it is from this area that we have the clearest picture of the decline. Here, site occupancy fell from 48% to 14% between 1981 and 1984 and remained at 14% in 1985 and 1986. Breeding success during 1975–81 varied from 46–60% (perhaps as high as 67%), except in the very wet year of 1979 when it fell to 19%. The mean breeding success in this period was 47–48% (or 53–54%, omitting 1979). Between 1982 and 1986, success varied from 0% to 50% with a mean of only 21%. In the latter period only 18 young were reared in the West Mainland with a further 17 elsewhere in Orkney. In the 5-year period prior to this, at least 106 young were reared in the West Mainland alone. Although occupancy was still low, 1987 was decidedly better with 80% breeding success and 11 young reared in the West Mainland (88% and 21 young in all Orkney). This improvement was perhaps the result of particularly good weather in the pre-laying period (see below).

The low production of young during 1982–86 was caused by a combination of low site occupancy, and poor breeding success the major cause of which was failure during incubation. Such failure may have resulted from accidental breakage, or deliberate eating, of the eggs by the adults; predation by avian or mammalian predators or man; or desertion. Without intensive nest surveillance, I could not determine which of these factors was of greatest importance. However, gradual clutch depletion eventually resulting in total failure would usually imply parental breakage or eating, while total disappearance of the clutch implies predation, or desertion followed by predation. The finding of eggshell remains in the nest scrape is inconclusive as they may result from breakage or predation. In general, however, small shell fragments found in the scrape are indicative of egg breakage while large (*c.* ½ egg) fragments suggest predation. The data in Table 4 show that up to 54% (25% observed depeletion plus 29% small shell fragments) of incubation failures may have been attributable to breakage.

Recent declines in Merlin populations elsewhere in Britain have been explained in various ways. Evidence from the Peak District[5] indicated that a major decline occurred in the 1950s. Loss and change of habitat, recreational disturbance, pesticide contamination and direct persecution were all examined, of which pesticides appeared to be the major factor. The study of a North Wales moor[17] is more comparable with the Orkney situation. There, breeding success declined after 1979, as did the number of pairs after 1981. The authors considered the possibilities of a fire, severe weather and pesticide contamination, but rejected all of these as primary causes although they did note a sudden increase in losses due to addling, egg breakage and the death of small young. They suggest that severe spring weather may have exacerbated the effects of organo-chlorines, and that DDE may not have been the only contaminant involved. In a continuing study of the Northumbrian population,[4] a general downward trend has been charted during 1974–83. As it had been shown[13] that breeding rate is now only slightly reduced by pesticide contamination, the authors considered three other possibilities: habitat in the breeding season, habitat outside the breeding season and population dynamics. Degradation of breeding habitat was not considered to be significant since large areas of apparently good habitat was devoid of Merlins. It was also thought unlikely that wintering habitat was important. An imbalance in the species' population dynamics was considered to be the major factor; too few young were being produced to offset adult mortality. In Northumbria, the low production appeared to be due to increased predation of chicks in ground nests by mammalian predators, a situation associated with the decline in gamekeeping. Despite their earlier findings, the authors also suggested that breeding success may well be depressed by continuing organo-chlorine contamination. Bibby[18] suggested that habitat degradation at many of his Welsh sites meant that they were also incapable of producing young at a sufficient rate to maintain the population. He considered that although the proximate causes of nesting failure were predation or food shortage, the ultimate cause may well have been declining habitat suitability.

#### Habitat loss and degradation

In Orkney, habitat loss and degradation have produced major changes in the environment. Between 1958–80, the area of moorland in the West Mainland declined from 11 809 ha to 9140 ha (a 23% loss) and during 1980–85 to 8239 ha (a further 10%).[19] Most of this has resulted from the ploughing and re-seeding of moorland for conversion into pasture for beef cattle. However, only one Merlin breeding site (not in the West Mainland) has actually been destroyed by such operations. Perhaps more important has been the degradation of substantial areas of moorland by burning and sheep grazing. During the early 1980s, sheep grazing increased markedly on several moorland areas. Between June 1979 and June 1986, the number of breeding ewes in Orkney rose from 29 847 to 45 030 (51%).[20] The greatest increase (23%) occurred betwen June 1982 and June 1984. The proportion of ewes on which Hill Livestock Compensatory Allowance is claimed is currently 40%, having declined by about 2% during 1979–86 (Department of Agriculture and Fisheries for Scotland, pers. comm.). Thus, the numbers of ewes on moorland areas has risen from *c.* 12 500 to *c.* 18 000 between 1979 and 1986, an increase of 44%.

Heather burning for Red Grouse *Lagopus lagopus* management has been carried out in Orkney on only a very small scale and, although burning as an 'end-of-winter' tradition is widespread, it is burning to benefit sheep grazing that has affected the largest moorland areas in recent years. In the West Mainland, of 29 known Merlin territories, 8 (28%) have been heavily grazed and burned within 1 km of the nest location during the present study. A further 6 (21%) have been burned for reasons other than grazing. Thus, 49% of West Mainland sites have suffered some form of habitat degradation. At 5 of these territories (17% of those known, 36% of those affected) the actual nest site suffered a deterioration in quality.



### Disturbance

Gamekeeping has never been important in Orkney, and has been non-existent in recent years. Disappearance of nest contents in 1981–87 was limited to 3 clutches and 1 brood. These were possibly the result of human predation but there was no evidence for this. Even if this was the cause, the losses are relatively unimportant in the overall picture. Indirect disturbance is more likely. Much Orkney moorland is cut over for peat for use as a domestic fuel, mostly during May–July at the height of the breeding season. However, only 4 (14%) of the West Mainland sites are close enough to active peat cutting to be affected. Only one of these sites was used during 1981–87, in fact in every year, and although failure occurred in 5 of the 7 years, on only one occasion could the cause have possibly been disturbance.

### Weather

Inclement weather is not considered to be a prime factor in the Orkney Merlins' decline. No breeding season in the period 1981–86 experienced the same amount of rainfall as did 1979 when breeding success was severely affected. However, the period has been notable for its cold, late springs which may prevent birds reaching peak condition as suggested for Sparrowhawks *Accipiter nisus*.[21] This, in turn, could exacerbate other detrimental factors. The pre-laying period in 1987 had much better weather than any of the previous 6 seasons and this may have led to improved breeding success.

### Predation

In contrast to the Northumbrian situation, mammalian predation of Merlin chicks has been shown to be unimportant. The only native ground predator is the uncommon Otter, although Feral Cats are quite common and stray dogs occasionally wander the moors. Only two nest failures could be attributed to mammalian predation of chicks.

Failures at the egg stage have been shown to be the major problem in Orkney. Only 3 out of 28 (11%) failures involved the complete disappearance of the clutch. At a further 6 (21%), the presence of large shell fragments may implicate a predator, and it is possible that predation was also involved at some of the 8 (29%) where small shell fragments were all that remained, although this is unlikely. Any predation of Merlin eggs in Orkney is most likely to be by Hooded Crows which have increased in recent years, perhaps as a result of the ever-increasing acreage of pasture (N. Picozzi, pers. comm.). They are a major predator of the eggs of the Hen Harrier *Circus cyaneus*, which nests commonly on the Orkney moors. However, in the 1971–76 study of Merlins in Northumberland,[3] only one example of egg predation by Crows was recorded and that probably after the clutch had already been deserted. Although it is impossible to be certain without intensive nest surveillance, it seems unlikely that predation of nest contents was the major cause of the decline in Orkney.

### Contamination by organo-chlorines

Failure of nesting attempts due to egg-breakage, depletion of clutches and the occurrence of infertile eggs in Merlins have been related to contamination by organo-chlorine pesticides. Levels of organo-chlorine compounds in British Merlin eggs were discussed by Newton *et al.*[13] who presented data consistent with the view that DDT-type compounds have caused shell-thinning. The geometric mean levels of organo-chlorines in 71 British Merlin eggs collected during 1971–80 were: 113.1 p.p.m. DDE (the metabolite of DDT), 89.7 p.p.m. PCB, and 7.59 p.p.m. HEOD. The mean shell index for British Merlin eggs collected in the pre-DDT era, 1870–1946, was 1.26 ($n$ = 182) declining to 1.16 in 1947–60 ($n$ = 27), 1.10 in 1961–70 ($n$ = 8) and 1.05 in 1971–80 ($n$ = 84). However, Newton *et al.*[13] concluded that DDE levels in eggs obtained in Britain during 1971–80 were below those likely to cause failure of the whole clutch. Nor did it seem likely that PCB or HEOD (from aldrin and dieldrin) levels were high enough to cause appreciable breeding failure. They acknowledged, however, that eggs are only obtained from a part of the population, and that non-laying individuals or birds failing soon after laying may be more contaminated.

Although DDT usage became increasingly restricted after about 1970 in Britain as a whole, it continued to be used for certain purposes. Moreover, as recently as spring 1981, the North of Scotland College of Agriculture was advocating its use on spring-sown barley and oats in their 'College Notes' column of 'The Orcadian' newspaper. However, although based on a small sample, organo-chlorine levels in Orkney Merlin eggs did not appear to be at a level high enough to be a major factor in the species' decline. Geometric mean levels of DDE and HEOD did not approach those found in eggs from the rest of Britain during 1971–80 (Table 6). Shell indices, usually directly correlated with DDE levels, were slightly above the national average. However, 25% of nest failures resulted from gradual depletion of the clutch, and a further 29% of failed nests showed the symptoms of egg breakage usually associated with shell thinning.

**Contamination by mercury**

The only contaminant occurring at a notably high level was mercury, with a geometric mean concentration of 5.75 p.p.m. dry weight. It has been shown[14] that the number of young raised by British Merlins is inversely related to the levels of Mercury in their eggs although this statistical relationship did not hold for Orkney and Shetland alone. The mean concentration in 115 eggs was 2 p.p.m. but levels in eggs collected in Orkney and Shetland were strikingly higher. Productivity was shown to fall markedly in clutches where mercury levels exceeded 3 p.p.m. All eggs collected in Orkney had levels in excess of this (Table 6), suggesting that mercury may indeed be reducing breeding success in the islands. It has been suggested that the higher levels of mercury in Merlin eggs from Orkney and Shetland may have resulted from a greater dependence on waders as prey, the waders in their turn having accumulated the mercury while wintering on contaminated estuaries.[14] However, at least during the breeding season, waders are unimportant in the diet of Orkney Merlins (Table 7). No study has been made of winter food, but casual observations suggest that Starlings, Redwings and the smaller shore waders are important and the latter may indeed be the mercury source. There is also the possibility that some Orkney Merlins winter away from the islands and become contaminated while in their winter quarters. A further possible source of the contamination may be House Sparrows. Orkney is similar to other Merlin breeding areas in Britain in that the Meadow Pipit is of greatest importance in the diet[3, 23, 24] while the Skylark, another open-country species, could be expected to figure prominently in an area where they are common. Orkney is, however, unique among British Merlin breeding areas in having such a high proportion of House Sparrows in the diet (Table 7) although this, too, is perhaps not unexpected considering the proximity of many of the breeding sites to farms and crofts. All barley sown in the islands is treated with oragno-mercury and it may be that the contaminant is transferred to Merlins feeding on sparrows which have fed on dressed grain. Such an explanation would not, however, hold for Shetland, where very little barley is grown and where House Sparrows are insigificant in the diet (D. Okill & P.M. Ellis, pers. comm.).

Thus, no one factor seems adequate to explain the decline of the Merlin in Orkney, with the possible exception of mercury contamination which evidently merits further research. Deterioration in habitat quality, together with the continuing presence of organo-chlorines and high levels of mercury in eggs, exacerbated at times by poor breeding season weather and predation by Crows, could all be acting together to adversely affect the population dynamics so that production of young is insufficient to compensate for adult mortality.

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# National pine marten population assessment


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Department of Arts, Heritage,
Regional, Rural and Gaeltacht Affairs

# National Pine Marten Population Assessment

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# Contents

# Executive Summary

Pine marten (*Martes martes*) are a protected species in Ireland and have recently undergone a natural range expansion after centuries of decline. Estimates of population abundance and of the conservation status of pine marten are required to meet national and international legislative requirements, and to inform effective management of the species.

In this study, variation in pine marten density and abundance was assessed in 19 forested study sites throughout Ireland, using non-invasive research techniques. Pine marten hair samples were collected and analysed using molecular methods to determine individual identity data for each pine marten captured. Density estimates were obtained using spatially explicit capture recapture models. This data was then used as the basis for determining a mean pine marten density across randomly selected study sites, which was combined with data on the current distribution and estimated habitat area occupied by the species, to provide a national pine marten population abundance assessment.

Across all study sites, a total of 134 individual pine marten were identified in 339 hair samples. In most study sites, the number of individual pine marten detected was low (≤ 10 individuals). Estimated pine marten density varied from 0 to 2.60 individuals per km$^2$ of forested habitat in randomly selected study sites, with all but a single site having an estimated density of ≤ 1 pine marten per km$^2$ of forest habitat. There was relatively little variation in density across the majority of random study sites. In preselected study sites, estimated pine marten density varied from 0.57 to 4.29 individuals per km$^2$. Across all randomly selected study sites, 93 individual pine marten were captured 217 times, and a mean density estimate of 0.64 (95% CI 0.49 - 0.81) pine marten per km$^2$ of forest habitat was determined. Combining this with data on the current distribution and area of forest habitat occupied by the species in Ireland, the total population abundance of pine marten in Ireland was estimated at 3,043 (95% CI 2,330 – 3,852) individuals.

This research involved the largest scale investigation of pine marten density and abundance in Ireland, and has determined that the species exists at low density throughout the majority of study sites investigated, with relatively little variation in density across these sites. A national population estimate of 3,043 individuals confirms, and reinforces, that pine marten are amongst the rarest of all mammalian species in Ireland and require careful conservation management to sustain the population and to meet international obligations for protection.

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# 1. Introduction

## 1.1 Pine marten biology, ecology and legal status

The European pine marten (*Martes martes*), also known as the tree cat (Cat crainn), is the only member of the genus *Martes* that is native to Ireland. Pine marten have a Palearctic distribution stretching from Siberia, Iran, across Europe to its most westerly range in Ireland. Other related species that occur in continental Europe include stone marten (*M. foina*) and sable (*M. zibellina*), the latter occurring mainly in Russia. A hybrid between pine marten and sable known as kidus occurs in the Ural Mountains, at the juncture between the continents of Europe and Asia. Pine marten belong to the family Mustelidae and are related to species such as the badger (*Meles meles*), otter (*Lutra lutra*) and stoat (*Mustela erminea*).

In appearance, pine marten have traits typical of other Mustelid species in that they are medium sized, have an elongate body (up to 50cm), short legs, a loping gait, small rounded ears, a long bushy tail (up to 25cm), and chestnut to dark brown fur. Additional distinctive features of the species include a creamy-yellow chest / throat patch, which can extend down its front legs and be of variable pattern, and a yellow or pale fringe to the ears. Pine marten are considered a forest dwelling species and are adept at tree climbing, aided by their bushy tail and strong claws. Where forest habitat is not available, the species can exist in scrub habitats and increasingly it is being acknowledged that pine marten are becoming more adaptable at exploiting open habitat once suitable forest cover exists nearby.

In terms of general ecology, individual pine marten are solitary (except for mating purposes) and have an intra-sexual system of territorial organisation, which at the population level can be very well structured (Powell 1979). Pine marten territories and home range size can vary from 0.5 - 20km$^2$, which can be influenced by habitat type, forest cover, gender, food abundance, season, habitat fragmentation and age-class of the individual (Zalewski & Jędrzejewski 2006). Within their home range pine marten will utilise a wide variety of refuge sites such as tree cavities, tree canopy and underground burrows that provide cover and protection when the species is at rest. Pine marten are typically nocturnally active and can travel several kilometers during periods of activity, which can be influenced by local ambient temperature (Zalewski 2000). Breeding in the species typically takes place between June and August after which there is delayed implantation for approximately six months. After a gestation period of thirty days, the young (kittens) are born in March or April in a den site that can be located in tree cavities, roots or rock outcrops and occasionally in attics of barns or houses.

Litters usually range in size from one to three individuals and maturity is reached within twelve months. Pine marten are opportunistic omnivores and have a broad and seasonally varied diet that includes small mammals, microtine rodents, invertebrates, amphibians, small birds, carrion and fruits/berries throughout their range (De Marinis & Messeti 1995). Life expectancy is typically 5-8 years for adult pine marten with substantial rates of annual mortality (i.e. 0.38-0.49: Zalewski & Jędrzejewski 2006). The species has a low reproductive output both in terms of its annual output (i.e. the number of young produced) and the age at which reproductive maturity is reached (Buskirk & Ruggiero 1994).

Pine marten receive full legal protection throughout the island of Ireland under the terms of the Wildlife Acts 1976 to 2012 and Wildlife (Northern Ireland) Order, 1985 (as amended). It is an offence to capture or kill a pine marten, or to destroy or disturb its place(s) of rest. The species also receives International protection on Annex V of the EU Habitats Directive [92/43/EEC] and Appendix III of the Bern Convention 1979. These legislative instruments obliges Ireland to ensure that the pine marten population remains in favourable conservation status and prohibits certain management methods that are capable of causing local disappearance of, or serious disturbance to, a population of the species.

## 1.2 An overview of pine marten research in Ireland

In general terms there have been few direct research studies that have focused on pine marten in Ireland and this is especially true prior to the onset of the new millennium. Previous to the 1970s, data on pine marten in Ireland largely consisted of incidental records of sightings derived from direct observations, trapping and taxidermist returns, as well as a few anecdotes about the status of the species (Stendall 1946; Stendall 1947; Ruttledge 1948; Deane 1952; King 1952; Rogers 1959; Moriarty 1961). Due to concerns about the conservation status of pine marten in Ireland in the 1970s and a complete lack of knowledge on their distribution and ecology, a national survey was undertaken (O'Sullivan 1983). That study surveyed 428 10km grid squares to detect pine marten using scats, direct sightings or other records. O'Sullivan (1983) determined that pine marten range and distribution had undergone major reductions, that the species was absent from areas and regions where it had been historically present and that the population was concentrated in forested areas of the mid-western region of Ireland. It was suggested that the major reduction in the species range was attributable to the continual loss and fragmentation of established woodland habitat, direct persecution of the pine marten and predator control programs that involved the use of poison baits and traps that were occurring throughout Ireland. Fairley (2001) collated existing information of pine marten distribution in Ireland from 1870 to 1975, which showed an increase in the number of counties reporting no records of pine marten. All of this evidence clearly pointed to the fact that during the 19$^{th}$ and 20$^{th}$

centuries the pine marten population was undergoing major and sustained declines in distribution and abundance throughout Ireland, caused by human mediated factors.

Sustained research on pine marten in Ireland did not occur until the mid 2000s. A key instrument that addressed many of our knowledge gaps on pine marten was a research project referred to as the National Pine Marten Survey (NPMS) of Ireland, which was instigated in 2005. The NPMS conducted a variety of studies on pine marten, on an island of Ireland basis, to investigate the current distribution, conservation status and ecology of the species (O'Mahony *et al.* 2005; O'Mahony *et al.* 2007a; O'Mahony 2007b; O'Mahony *et al.* 2008(a); O'Mahony *et al.* 2008(b); O'Mahony 2009; O'Mahony *et al.* 2012; O'Mahony 2014). Various studies from the NPMS determined a significant pine marten range expansion had occurred in Ireland over the last 30 years (O'Mahony *et al.* 2012), provided the basis for a species conservation assessment to fulfil reporting requirements of the Habitats Directive (O'Mahony 2007b), produced the first national population abundance estimates for pine marten (O'Mahony *et al.* 2012), and completed the first radio-tracking based spatial ecology and habitat utilisation research on pine marten (O'Mahony 2009; O'Mahony 2014).

Further recent studies on pine marten in Ireland have concentrated on dietary analysis using traditional and molecular methods (Lynch & McCann 2007; O'Meara *et al.* 2014; Sheehy *et al.* 2014), questionnaire based distribution surveys (Carey *et al.* 2007), some parasitological investigations (Stuart *et al.* 2010; Stuart *et al.* 2013), studies that have aimed to determine pine marten abundance in different regions (Lynch *et al.* 2006; Mullins *et al.* 2010; O'Mahony 2014; Sheehy *et al.* 2014) and species distribution modelling (O'Mahony 2017).

## 1.3 Pine marten status and conservation in Ireland

Although the origin of the pine marten population in Ireland is subject to debate, whether it was present prior to the last glacial maximum or was introduced by humans, evidence suggests that pine marten have been in Ireland for thousands of years and are considered a native species. Historically pine marten would have been present throughout Ireland and would have inhabited the natural forests that dominated Ireland up until the 16th century. The species was likely to always have been exploited by humans due to its valuable fur. However, it was not until the 16th century that large-scale commercial exploitation of the species as a fur-bearer started, with evidence of tens of thousands of pelts being exported to England during that time period (Hickey 2012). This, coupled with the destruction of native forests from an estimated 95% cover to 1% at the onset of the 1900s (EPA 2006) could only have had a severe negative impact on pine marten population abundance and distribution throughout Ireland. During the rise of game estates in Ireland, pine marten along with a suite of other predators were persecuted through trapping, poisoning and shooting as 'vermin', and throughout that period and continuing to this day, to a lesser extent, indiscriminate deployment of poison baits that 'target' species such as foxes and corvids also had an impact on the species.

The cumulative effect of these various ad hoc 'campaigns' against pine marten in Ireland was that by the 20th Century, and probably earlier, the population had become extirpated throughout most of the country, with only a few isolated strongholds where the population persisted (O'Sullivan 1983). Full legal protection was enacted under the Wildlife Acts (1976) and subsequent International legislation including the Bern Convention and Habitats Directive. Since that low point for the population, increasing forest cover, less direct persecution, legal protection, the banning of poisons and potential deliberate releases have provided for a natural range expansion of pine marten (O'Mahony *et al.* 2012), such that the species is now probably more common than any time in the last 100 years. However, it must be emphasised that whilst the pine marten population is recovering in Ireland, the species remains one of our rarest terrestrial mammals with a population estimate of *ca.* 2,700 breeding individuals (O'Mahony *et al.* 2012). The recent conservation assessment of the species deemed pine marten to be of favorable status in Ireland (NPWS 2013). However, the re-occupation of the species former historic range and increasing abundance is likely to bring the species into increasing conflict with human interests (O'Mahony *et al.* 2012). If this is not managed properly, through research, education and adequate mitigation measures, increased rates of illegal persecution are likely to occur, which could cause future local population extirpations or even range contraction of pine marten in Ireland (O'Mahony *et al.* 2012). Indeed recent adverse media attention and calls for control attest to the requirement for urgent action in terms of education, mitigation and research to ensure the viability of this species in the long-term in Ireland.

## 1.4 Aims of current study

The scientific base of our knowledge on pine marten in Ireland is currently not adequate to address key issues that face the population into the future. In this study, pine marten population density estimates were investigated in multiple study sites located across Ireland. This data provided the basis for estimation of the national population abundance of pine marten in Ireland. This study also conducted an assessment of the current conservation status of pine marten in Ireland, which will help inform Article 17 requirements for this species under the Habitats Directive. Recommendations for the future monitoring of this species are also provided

# 2. Methods

## 2.1 Background to use survey methods

Hair tubes were first developed for martens in Canada (Foran *et al.* 1997) and by the Vincent Wildlife Trust in the UK (Messenger & Birks 2000), with the former using sticky patches and the latter springs to collect hair. The spring type traps were used in Co. Kerry (Lynch *et al.* 2006). In 2006, a novel hair trap using lightweight PVC tubing and efficient sticky patches was developed (Mullins *et al.* 2010). These were applied in trial surveys in Co. Mayo and Co. Galway and in a long term survey in Co. Waterford. In the most recent surveys, the samples obtained were used for population estimation by microsatellite analysis of DNA extracted from the hair samples (Mullins *et al.* 2010; O'Mahony *et al.* 2015). In all these surveys a similar pattern was observed, a low early success rate and a progressive increase in the number of samples obtained in subsequent trap sessions. In most surveys the success rate increased to over 50% of the tubes yielding samples. In all cases pine marten were detected. These surveys are summarised below (Table 1).

Table 1. Summary of previous hair tube surveys in Ireland.

| Site | Year | Type | Tube number | Genotype | Reference |
|---|---|---|---|---|---|
| Sheskin, Co. Mayo | 2006 | Sticky | 10 | No | Unpublished |
| Cloosh, Co. Galway | 2006 | Sticky | 10 | No | Unpublished |
| Killarney National Park, Co. Kerry | 2006 | Spring | 50 | No | Lynch *et al.* (2006) |
| Portlaw, Co. Waterford. | 2006-16 | Sticky | 20-25 | Yes | Mullins *et al.* (2010) |
| Mourne, Co. Down | 2011 | Sticky | 126 | Yes | O'Mahony *et al.* (2015) |
| Corbally, Co. Kilkenny | 2014 | Sticky | 12 | Yes | Power (2016) |
| Kilsheelan, Co. Waterford | 2015 | Sticky | 10 | Yes | Unpublished |
| Crom, Co. Fermanagh | 2014 | Sticky | 40 | Yes | O'Mahony unpubl |
| Castleward, Co. Down | 2014 | Sticky | 15 | Yes | O'Mahony unpubl |
| Midlands, Ireland | 2014 | Spring | 28 | Yes | Sheehy *et al.* 2014 |

## 2.2 Study site selection

A random sampling design was used to sample the pine marten population in Ireland throughout the species known current range. This involved selecting the majority of study sites randomly (n = 14), and surveying a number of additional preselected study sites (n = 5). It may be better described as a random-hybrid sampling design as most of the sites were randomly selected and a reduced number of sites were selected *a priori*. The term study site in this report refers to the individual 19 x 10km grid squares (Fig 1), within which surveys of suitable habitat formed the basis of density estimation for pine marten. As the target species is considered to require woodland habitat for population persistence, only areas of forest that occurred within the current distribution of pine marten were surveyed. Individual study sites were chosen using pine marten distribution data from O'Mahony *et al.* (2012) and records from the National Biodiversity Data Centre (www.biodiversityireland.ie). Combining this distribution data with various forestry and landuse GIS layers for Ireland (i.e. Forestry 12 and Coillte forest maps) in ArcMap 10.3 (ESRI systems), 14 x 10km grid squares were randomly selected that contained at least 200ha of woodland habitat within known pine marten distributional range. Where an initial randomly selected 10km grid square was not possible to survey (n = 2) for reasons related to the unavailability of landowner permission and site access, a random selection of an adjacent 10km that had at least 200ha of woodland habitat was undertaken. In addition to the randomly selected grid squares, project funders (NPWS) had identified 3 specific sites that were required to be surveyed for pine marten density (Ballycroy, Killarney and Wicklow National Parks). A further 2 pre-selected sites (Cong Forest and Dromore Wood Nature Reserve) were surveyed on the basis of having long-established pine marten populations in some of the last, most pristine remnants of semi-natural native woodland in Ireland, and were sites of potentially high suitability for pine marten.

Each study site was assessed and its total forest cover determined using GIS datasets in ArcMap 10.3. The majority of the forests surveyed in the current study were owned by Coillte (www.coillte.ie), who provided permission to access all of their forest estate. Attempts were also made to obtain similar permission from local private forest landowners and where this was available such sites were surveyed. Coillte are the largest single owner of forestry in Ireland, with over 445,000 hectares of land. Due to logistical constraints including the requirement to complete all of the surveys within a relatively short sampling timeframe (i.e. 5 months), the maximum number of hair tubes that could be surveyed at any one site was 30 tubes. We aimed to have an approximate tube density of 3 hair tubes per 100ha, a similar tube density to other studies that have used this methodology (O'Mahony *et al.* 2015). In each individual study site that had less than 1,000ha of forest cover, all accessible habitat was surveyed. Where more than 1,000ha of forest occurred in an individual study site, then a sub-sampling approach was adopted wherein each separate block or unit of forest was provided with a unique identity, and forest blocks that were surveyed were randomly selected so that the approximately 30 tubes or an equivalent habitat area of approximately 1,000ha was surveyed.

Once forests that were to be surveyed were identified in each study site then experienced field surveyors were provided with GPS positions of potential hair tube deployment locations. Field surveyors then deployed tubes in study sites either at, or close to, the hair tube grid provided and these individual surveyors made field-based decisions on tube locations based on site specific data such as forest management considerations, recent felling and unsuitable or inaccessible habitat. All study sites, apart from the 3 preselected National Park sites, were surveyed by trained field surveyors employed as part of the project. Project field surveyors trained NPWS staff at each National Park site and provided those staff with all necessary equipment to complete their surveys. All study sites were surveyed between January and June 2016.

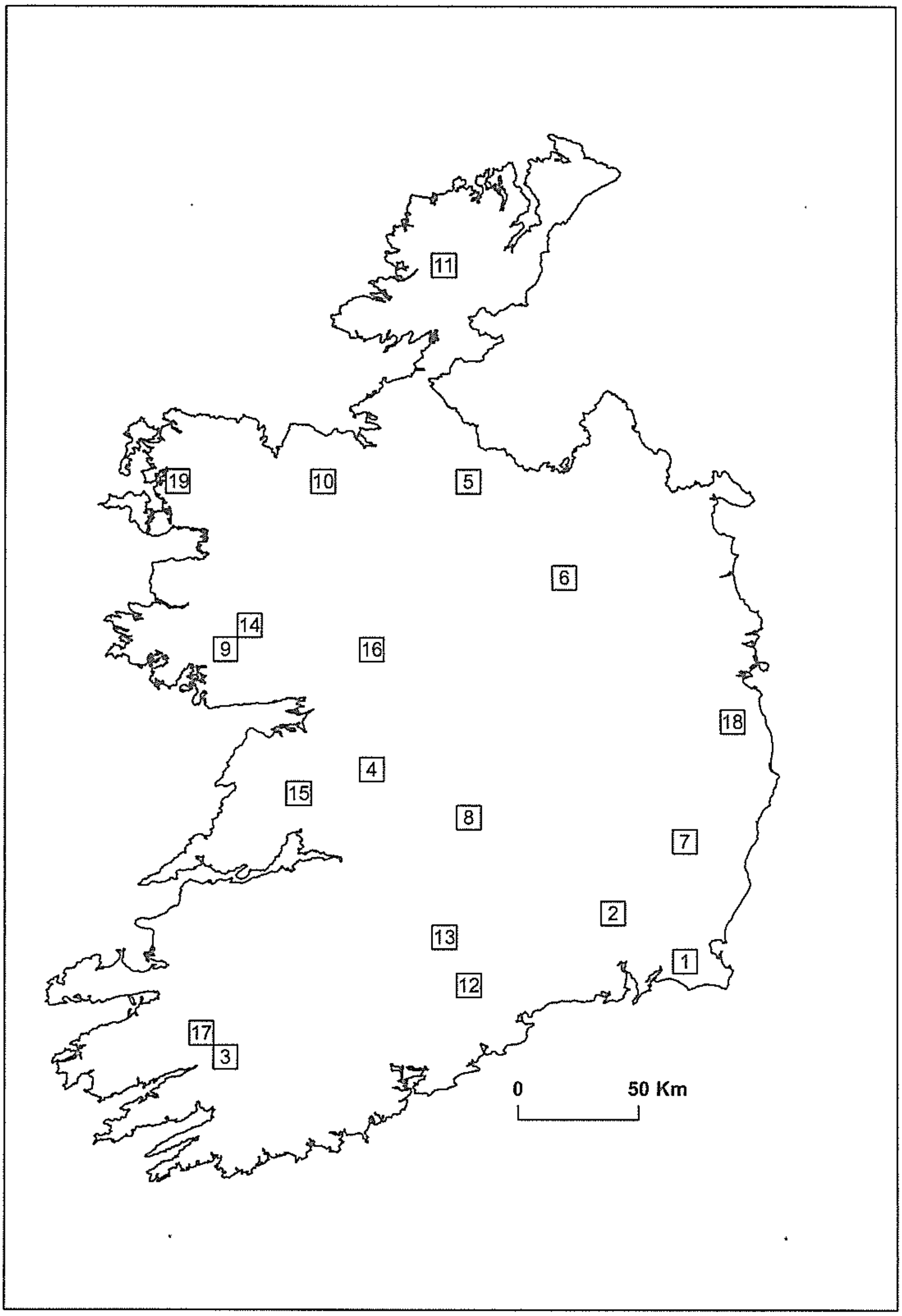


Figure 1. Location of 19 study sites surveyed to estimate pine marten density in Ireland during 2016. Randomly selected study sites are 1-13 and 16; preselected study sites are 14, 15, 17-19.

## 2.3 Sample collection and genetic analyses

### 2.3.1 *Hair capture*

Hair samples were collected by means of hair traps developed at Waterford Institute of Technology (WIT; Mullins *et al.* 2010). These consisted of plastic tubes (250x118mm) fixed vertically to trees and closed at the top. Tubes were baited with raw chicken tightly wired in the top of the tube. Hair was captured as the pine marten pressed against sticky patches at the tube entrance in order to remove the bait. Sticky patches were made from 1.5x2.5x0.3cm squares of hollow plastic board wrapped in double sided tape. Hair capture was on 1cm x 1cm squares cut from mouse glue trap. As the use of such glue traps is illegal in Ireland these were cut into squares before import in order to prevent their use as mouse traps. Tubes were fixed to trees using galvanised wire which allowed adjustment to compensate for tree growth as necessary.

### 2.3.2 *Sample collection*

Each study site was surveyed for approximately one month. During the first week in any study site, field surveyors deployed hair tubes and recorded locations with a Garmin 62 handheld GPS unit. At 5-7 day intervals, field surveyors re-visited each tube in each study site and ascertained whether or not hair samples were present. If hair samples were present then the sticky patches were removed from the tube and placed in a labeled sample tube for storage at -20°C. New sticky patches were then placed in the hair tube. If tubes had not been visited, the bait was replaced but clean sticky patches were left in situ. In total, each tube in each study site was visited on three sampling occasions, with tubes removed during the last sampling session. Tubes that were removed were cleaned and reused in other study sites.

### 2.3.3 *DNA Extraction*

Hair samples (ideally 10 hairs or more) were recovered from sticky patches using 1-2 drops of xylene to soften the glue and hairs were transferred to 1.5ml microfuge tubes using forceps. Forceps were heated to red heat and cooled between samples to prevent cross contamination. Hair was digested in 1.5ml microfuge tubes containing 90µl HPLC grade water; 90µl 2x digestion buffer (ZR Genomic DNA II Kit™ (ZYMO Research, CA, USA)); 10µl 20mg/ml Proteinase and 10µl 1M-dithiotreitol (Sigma-Aldritch). Digestion was at 56°C for 1-3h using a shaking heating block. DNA was purified using ZR

Genomic DNA II Kit™ (ZYMO Research, CA, USA) according to appropriate manufacturer's method. Final eluates were stored at -20°C.

#### 2.3.4 *Genetic analysis*

Real-time quantitative PCR (qPCR) assays for species and sex identification were carried out as described in Mullins *et al.* (2010). Two PCR replicates were carried out for molecular sexing (Lynch *et al.* 2006). Females were identified through the amplification of ZFX only, while a signal from both ZFX and ZFY probes indicated male DNA was amplified. The ZFX allele therefore acted as an internal amplification control for the assay.

Microsatellite analysis to identify individual pine marten was carried out using six microsatellite markers. These were: Gg7; Ma2; Mel1; Mvi1341, (Mullins *et al.* 2010) and Mar21 and Mar43 (Natali *et al.* 2010). Each sample was analysed in triplicate and only samples giving identical results in the replicates were scored. Genotype data were analysed for probability of identity (PI and PI*sibs*), observed ($H_o$) and expected ($H_e$) heterozygosity and allele frequencies using GENALEX version 6 (Peakall & Smouse 2006).

### 2.4 Density and abundance estimation modelling at regional and the national scale

#### 2.4.1 *Background to density and abundance estimation*

We used a study design and statistical analysis framework in the current study that was similar to that of O'Mahony *et al.* (2015), a study which conducted the hitherto largest scale population density research on Irish pine marten. The methods were also consistent with density and abundance studies for related species such as American marten *M. americana* (Mowat & Paetkau 2002) and wolverine *Gulo gulo* (Royle *et al.* 2011) in terms of design and analyses. Non-invasively collected hair samples combined with capture-mark-recapture analysis techniques provided the basis for density estimation in the current study, with collected hair samples being species typed, sexed and genotyped using molecular techniques. For each study site, this data provided the unique individual identity data and capture histories for each individual that could be used in capture recapture statistical approaches.

Following O'Mahony *et al.* (2015), spatially explicit capture recapture (secr), also referred to as spatial capture recapture (scr), analyses were used to determine study site specific, and national population density and abundance of pine marten in Ireland. Spatially explicit capture recapture modeling is a recent advancement on traditional forms of capture recapture analyses in that the technique includes spatial information on an individual's capture and home range activity centers inferred from provided spatial data, to model population density, overcoming issues associated with non-spatial estimation techniques such as edge effects (Efford 2004a; Efford *et al.* 2004b; Royle *et al.* 2009; Borchers & Fewster 2016). Spatially explicit capture recapture techniques are increasingly being used in density estimation studies of species of conservation and management concern throughout the world (Karanth 1995; Royle *et al.* 2011; Gray & Prum 2012; Head *et al.* 2013; Rouco *et al.* 2013; Anile *et al.* 2014; Borchers *et al.* 2014; Stetz *et al.* 2014; Dumond *et al.* 2015; Morin *et al.* 2016; Sirén *et al.* 2016).

Spatially explicit capture recapture models are primarily used where populations are closed and can estimate density and abundance, whereas non-spatial capture recapture can only determine abundance, which then needs to be divided by an estimated effective sampling area to obtain density estimates for a population of interest, which can lead to biased estimates (Efford 2004a). Spatially explicit capture recapture uses inverse prediction (Efford *et al.* 2004b), maximum likelihood (Borchers and Efford 2008) or Bayesian based estimation methods (Royle *et al.* 2009) to estimate three main parameters: the magnitude of individual capture probability (g0), the spatial scale (σ) over which capture probability declines, and population density (D) (Efford 2004a). Ancillary information provided in secr analyses include configuration of detectors or traps (i.e. hair tubes), the type of spatial point process (i.e. Poisson), models of detection events, habitat mask(s) and the s hape of the spatial detection function (Efford *et al.* 2004b). Spatially explicit capture recapture models can account for biologically relevant forms of heterogeneity in capture probabilities and home range size, avoids assumptions of geographic closure, variance in density is estimated directly from fitted spatial models and reflects all forms of uncertainty and process variation included in the model (Obbard *et al.* 2010). Spatially explicit capture recapture based analyses can also produce more reliable estimates for populations with small sample size of individuals, as compared to more traditional non-spatial capture recapture, particularly when relatively simple models are implemented (Borchers & Efford 2008; Royle *et al.* 2009; Sollman *et al.* 2011). Current knowledge of pine marten densities in Ireland suggests that populations largely consist of relatively small numbers of individuals (Lynch *et al.* 2006; O'Mahony 2014; Sheehy *et al.* 2014, O'Mahony *et al.* 2015) in any single location. The program CAPWIRE (Miller *et al.* 2005) was used for population abundance estimation, this was designed for studies such as this, where individuals are not held but are released after sampling, i.e. recapture is allowed within sessions.

### 2.4.2 Assumptions of density estimation

Spatially explicit capture recapture analysis, like all statistical models, has several underlying assumptions including: the population is closed; animals are captured with certainty and captures do not affect movement patterns of the animal within a trapping session; hair tubes are located at known locations for a fixed time period; animal tags are not lost and animal capture location(s) are recorded accurately; hair tube placement is random with respect to the range of an animal, which are orientated randomly; animal home ranges are circular, do not change during a trapping session and follow a Poisson distribution within the sampled area; and that detection occurs independently for each animal (Efford *et al.* 2004b)

In the current study, each study site had 3 sampling occasions that lasted 1 week each (i.e. 3 weeks sampling in each study site), which was a very short sampling period and consistent with population closure at the study site level. By using non-invasive genetics techniques it was ensured that animals were captured with certainty and tags could obviously not be lost. Utilising hair tubes as a trap type did not interfere with animal movement patterns during sampling sessions as animals were not restrained. Hair tube locations were permanently marked with GPS, were placed systematically through the surveyed area and therefore could be considered random with respect to animal ranges. Pine marten home ranges are generally stable over the medium-long term, and certainly over the duration of the sampling occasions in this study (i.e. 3 weeks). Although pine marten home ranges are generally not circular (O'Mahony 2014), violation of this assumption may only effect variance in D and not density estimates directly (Efford *et al.* 2004b; Obbard *et al.* 2010). Pine marten exhibit mutual avoidance of individuals with overlapping home ranges, rather than spacing themselves evenly, therefore, randomly distributed home range centre locations may be a reasonable approximation in the current study (see Obbard *et al.* 2010). Pine marten biology and ecology, combined with the survey design deployed in this study maximised likely fulfilment of key assumptions of secr, and it is suggested that potential violation of assumptions on home range may not have severely biased secr based density estimates in any case (Obbard *et al.* 2010).

### 2.4.3 *Pine marten density estimates in individual study sites*

Using the genotyped data for each individual pine marten detected in each specific study site, capture histories were created for each sampling occasion (n = 3 per study site). For secr analysis, the detector type chosen was 'proximity' to allow for multiple individuals to be captured at the same location; a Poisson distribution of home range centers was specified; and probability density functions were modeled using half-normal processes. Half normal spatial capture probability functions are commonly used in secr analyses (Dumond *et al.* 2015) and assume that the probability of pine marten capture increases linearly with proximity of a hair tube to the home range of an individual, which is biologically reasonable. As the sample size of the number of individual pine marten and associated capture rates were generally low for each site (Table 2), it was advisable that relatively simple models of detection and spatial processes would be the most biologically meaningful (Royle *et al.* 2009; O'Brien & Kinnaird 2011).

As it is known that pine marten ecology, behaviour and spacing patterns can vary between males and females (Zalewski & Jedrzejewski 2006; O'Mahony 2014), and that these ecological differences may have affected capture probabilities and spatial scales within the current study, it was important to account for this when estimating pine marten density. A hybrid mixture model was implemented in secr (Efford 2016) to account for variation in capture probability and spatial scale by sex in the current study. The hybrid mixture model uses the hcov command in package *secr* and refers to a flexible combination of latent classes (as in a finite mixture) and known classes (cf groups or sessions) (Efford 2016). In addition to models that accounted for sex, models that specified a behavioural response to capture *b*, whether an animal had been previously detected at a specific site *bk*, and sampling time occasion effect models *t* were also implemented in effecting capture probability (g0). A null model, where detection and movement parameters were assumed to be equal amongst individuals and sexes was also specified. Overall model selection was based on the lowest Akaike Information Criterion value, corrected for small samples sizes (AICc). Where candidate models were closely related to each other, model averaging was undertaken.

A habitat mask that incorporated a map of surveyed forests, tube locations and a specific buffer zone around this surveyed habitat is an important concept in secr based analyses (Efford *et al.* 2004b). The buffer distance should be sufficiently large to ensure that all animals with a negligible probability of encounter are included (Royle & Converse 2014). The size of the buffer distance is a function of the movement parameters of the species of interest and should generally be 3 times sigma (home range size) to minimise bias in density estimation (Efford *et al.* 2004b). In this study a buffer zone distance of 2,000m was specified on the basis of that being approximately 4 home range centers in size for pine marten in Ireland (O'Mahony 2014). This distance is within the range of pine marten daily activity movement in Ireland (O'Mahony unpubl) and accounted for potential movement of individuals in the buffer area around the study sites. A habitat mask was created in ArcMap 10.3, which included the forest area within which hair tubes were deployed, and a 2,000m buffer around that surveyed area that only contained suitable habitat for pine marten (i.e. forests). Density was expressed as number of pine marten per $km^2$ of forest habitat. All density estimation was undertaken using package *secr* (Efford 2016) in R version 3.3.1 (R Core Development Team 2016), with some preliminary data exploration in Density 5.0 (Efford *et al.* 2004b). In secr analyses, data were simultaneously modeled with each candidate model. The most parsimonious model was then fitted to each individual study sites unique capture data, trap and habitat mask area configurations to derive site specific density estimates. The 14 randomly selected study site dataset and preselected 5 study sites dataset were analysed using the exact same means as described above, but using separate coding in package *secr*. Site specific and across site abundance estimates were obtained using CAPWIRE (Miller *et al.* 2005).

### 2.4.4 National density and population of pine marten in Ireland

To estimate a national mean density for pine marten across sampling sites, all capture recapture data from each sampling occasion across the 14 randomly selected study sites were pooled into a single database. The habitat area and tube locations from site 7, where no pine marten were detected in this study and density was assumed to be zero, were included in analyses. A pooled habitat mask was created in ArcMap 10.3 that included all the combined habitat area surveyed in each individual site and this was buffered by 2,000m (see section 2.4). The best performing secr model (see section 2.4.3) was then applied to the pooled dataset. CAPWIRE was also applied to the 14 randomly selected sites to obtain an overall abundance estimate for these study sites.

This mean pine marten population density was scaled to a national pine marten population abundance estimate for Ireland by incorporating data from the current distribution of pine marten in Ireland (see Fig. 2) and quantifying all of the available forest habitat within that distribution, as determined from various GIS datasets (see section 2.2). This approach is frequently used when data on regional or national population abundance estimates are required for species of interest (Erb & Sampson 2009; Frary *et al.* 2011; O'Mahony *et al.* 2012; Fechter & Storch, 2014; Humm *et al.* 2015; Gervasi *et al.* 2016). It obviously has underlying assumptions that include current knowledge on pine marten distribution is correct, study sites are randomly selected, all available habitat in the species distribution is occupied by pine marten, GIS layers are accurate and habitat suitability is accounted for. As pine marten are a relative habitat specialist and are dependent on forested habitat, the basis for scaling up density estimates in terms of the availability of suitable habitat in the current study is well founded.

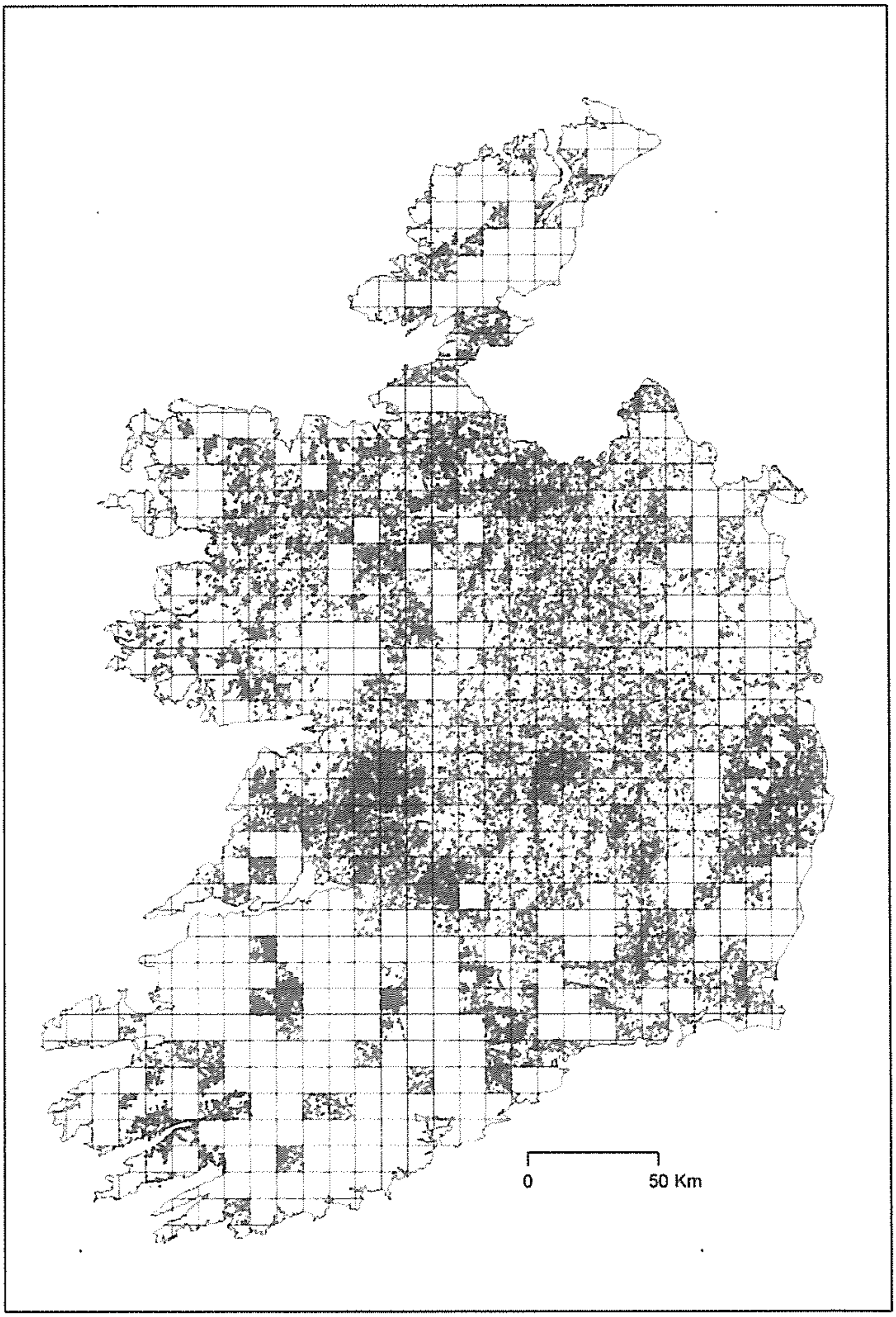


Figure 2. The distribution of forestry within the current pine marten range in Ireland as represented at the 10km square level. Pine marten distribution data provided by the National Biodiversity Data Centre from records of pine marten between 2010 and 2015.

# 3. Results

## 3.1 Overview of data presented in the study

In the current study we present the full dataset that included all tubes and study sites surveyed in the current project (Table 2). This data included study sites for which no pine marten were detected (site 7), and hence, density was treated as zero, and site 18, which for data specific reasons could not be included in analyses. Within the data there are effectively 2 datasets, one for the 14 randomly selected study sites (1-13 and 16; see Fig. 1) and one for 5 preselected sites (14, 15-17-19; see Fig. 1; see section 2.2). Density and abundance estimates were derived for all of the 14 random sites, and to determine a mean density across these random study sites, as a basis for national population assessment. Even though surveys in site 7 did not detect pine marten, the habitat area of this site was included in mean density estimation across sites (see section 2.4.4). The preselected data, which included site 18, was targeted at specific sites in the country for *a priori* reasons (see section 2.2) and, apart from site 18, pine marten density and abundance was estimated to assess the magnitude of pine marten density in these sites that included habitat considered to be highly suitable.

## 3.2 Hair tube surveys

A total of 339 hair samples were collected from 537 hair tubes deployed throughout the 19 study sites (Table 2). The number of hair samples collected per study site varied from 0 to 40. DNA analysis verified that 97% of the hair samples were pine marten and 89% of those yielded genotypes with the six microsatellite loci. All loci were polymorphic with 3-4 alleles per locus. The probability of identity (PI) using all six loci was PI = 0.00042 and PI*sibs* = 0.024. No deviation from Hardy-Weinberg equilibrium was observed.

In total, 134 unique individual pine marten were determined across all study sites, 71 male and 60 female (3 were undetermined), and 0 to 19 individuals were detected per study site. Across the 19 study sites, 37.6% of hair tubes yielded pine marten hair samples (212/537), ranging from 0% to 90% of tubes per study site (Table 2). The total return on tubes was 63% (339 hair samples from 537 tubes). Across sampling sessions the number of unique individual pine marten captured did not significantly differ between sessions $\chi^2 = 1.78$, $df = 2$, $P > 0.40$ (session 1 = 37, session 2 = 46, session 3 = 48), and the levels of animal recaptures increased as sampling sessions progressed (session 1 = 37, session 2 = 68, session 3 = 95). Across all study sites and sampling sessions, on average, individual pine marten had a recapture rate of 2.20 (SE 0.16; range 1-11), with 52.95% of individuals detected once, and 47.05% of pine marten captured more than once (Fig. 3). Few individual pine marten were captured 5 or more times within the study (Fig. 3). In a similar pattern as observed with pine marten captures rates, on average, pine marten were captured in 1.58 unique hair tubes (SE 0.08; range 1-5), which does not include re-use of the same tube.

Table 2. Summary of pine marten capture data for each study site. Hair samples were defined as pine marten by DNA analysis and as individuals by unique genotypes at the initial six microsatellite loci. Recapture rate is the mean for each sample set. Na, not applicable. "All" represents data pooled for all sites and "Random" shows data pooled from the 14 randomly selected sites (*).

| Site Code | Number of Tubes | Hair Samples | | Pine marten Hair | | Sex Type | | Genotyped Samples | | Unique Genotypes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | return | n | % of hair | n | %male | n | % marten | n | recapture rate |
| 1* | 24 | 11 | 0.46 | 11 | 100% | 10 | 40% | 10 | 91% | 6 | 1.67 |
| 2* | 30 | 34 | 1.13 | 34 | 100% | 32 | 56% | 27 | 79% | 9 | 3.00 |
| 3* | 29 | 23 | 0.79 | 19 | 83% | 17 | 82% | 18 | 95% | 8 | 2.25 |
| 4* | 30 | 21 | 0.70 | 21 | 100% | 20 | 55% | 20 | 95% | 10 | 2.00 |
| 5* | 30 | 16 | 0.53 | 16 | 100% | 16 | 81% | 16 | 100% | 5 | 3.20 |
| 6* | 23 | 11 | 0.48 | 11 | 100% | 11 | 45% | 11 | 100% | 6 | 1.83 |
| 7* | 30 | 0 | 0.00 | 0 | na | na | na | 0 | na | 0 | na |
| 8* | 31 | 20 | 0.65 | 20 | 100% | 20 | 85% | 20 | 100% | 11 | 1.82 |
| 9* | 30 | 16 | 0.53 | 16 | 100% | 16 | 63% | 15 | 94% | 6 | 2.50 |
| 10* | 30 | 25 | 0.83 | 25 | 100% | 23 | 70% | 22 | 88% | 8 | 2.75 |
| 11* | 25 | 2 | 0.08 | 2 | 100% | 2 | 100% | 2 | 100% | 1 | 2.00 |
| 12* | 26 | 4 | 0.15 | 3 | 75% | 2 | 100% | 2 | 67% | 2 | 1.00 |
| 13* | 30 | 26 | 0.87 | 24 | 92% | 18 | 67% | 16 | 67% | 7 | 2.29 |
| 14 | 30 | 40 | 1.33 | 39 | 98% | 38 | 55% | 31 | 79% | 19 | 1.63 |
| 15 | 30 | 21 | 0.70 | 21 | 100% | 21 | 81% | 21 | 100% | 8 | 2.63 |
| 16* | 22 | 38 | 1.73 | 38 | 100% | 38 | 37% | 38 | 100% | 14 | 2.71 |
| 17 | 27 | 12 | 0.44 | 11 | 92% | 11 | 18% | 11 | 100% | 7 | 1.57 |
| 18 | 30 | 6 | 0.20 | 4 | 67% | 4 | 50% | 4 | 100% | 3 | 1.33 |
| 19 | 30 | 13 | 0.43 | 13 | 100% | 9 | 89% | 9 | 69% | 4 | 2.25 |
| All | 537 | 339 | 63% | 329 | 97% | 309 | 60% | 293 | 89% | 134 | 2.20 |
| Random | 390 | 247 | 63% | 240 | 97% | 225 | 60% | 217 | 90% | 93 | 2.30 |

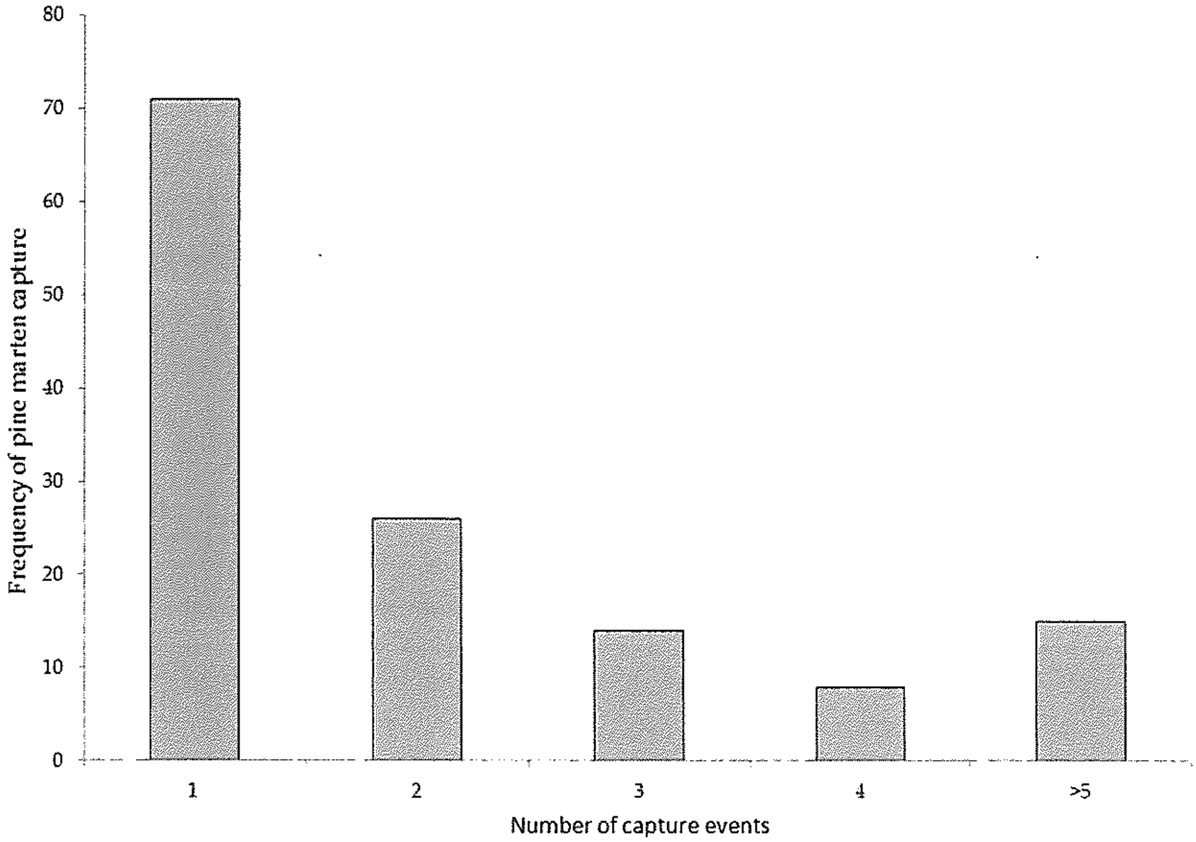


Figure 3. Capture frequencies of individual pine marten across all study sites.

## 3.3 Study site variation in estimated pine marten density and abundance

Density and abundance estimates were obtained for 18 out of the 19 study sites across Ireland. Based on secr analyses the best performing models were hybrid mixture models that included sex and site specific detection effects on pine marten capture probability and sex effects on spatial scale for both the random, and preselected study sites data (Table 3). The estimated habitat mask area including all forested habitat within a 2,000m buffer of all surveyed sites was 36,041ha (Table 4). Estimated pine marten density varied from 0 to 2.60 pine marten per $km^2$ of forested habitat in random sites (Table 4; Fig. 4). In all but a single random site, pine marten density estimates were below 1 individual per $km^2$ of forest habitat. Confidence intervals associated with density estimates from random study sites overlapped for most of the study sites (Fig. 4), with the exception of study site 16, which was significantly greater than other sites. In preselected study sites, estimated pine marten density varied from 0.57 to 4.29 pine marten per $km^2$ of forest (Table 4, Fig. 5). Abundance estimates of pine marten for each study site, based on using CAPWIRE, are shown in Table 5. For CAPWIRE abundance analyses, the TIRM model was implemented on combined capture data across each sampling session, in each study site. Estimates of pine marten abundance ranged from 6-39 individual pine marten across all study sites (Table 5).

Table 3. Akaike information criterion (AIC) model selection for spatially explicit capture recapture analyses of pine marten density. Model specified capture probability at home range center (g0), and spatial scale (σ), modelled with variation in sex (h2), individual behaviour response to capture (b), whether an animal had been previously detected at a specific site (bk), sampling time occasion effect models (t), and null model (1). Number of parameters (npar), log-likelihood (LogL), AICc is AIC with a correction for finite sample sizes.

| Data | Model | npar | LogL | AIC | AICc |
|---|---|---|---|---|---|
| Random Sites | g0~bk + h2, σ ~ h2 | 7 | -732.18 | 1478.36 | 1479.68 |
| | g0~b + h2, σ ~ h2 | 7 | -768.47 | 1550.94 | 1552.26 |
| | g0~t + h2, σ ~ h2 | 8 | -769.34 | 1554.67 | 1556.39 |
| | g0~ h2, σ ~ h2 | 6 | -796.61 | 1605.23 | 1606.20 |
| | g0~1, σ ~ 1 | 4 | -802.35 | 1612.69 | 1613.15 |
| Preselected sites | g0~bk + h2, σ ~ h2 | 7 | -250.21 | 514.42 | 518.28 |
| | g0~t + h2, σ ~ h2 | 8 | -263.20 | 542.41 | 547.55 |
| | g0~b + h2, σ ~ h2 | 7 | -266.77 | 547.53 | 551.39 |
| | g0~ h2, σ ~ h2 | 6 | -272.22 | 556.43 | 559.23 |
| | g0~1, σ ~ 1 | 4 | -281.45 | 570.90 | 572.15 |

Table 4. Pine marten density estimates for each study site using secr based analysis of pine marten capture data across 19 study sites in Ireland. No density estimates could be derived for site 18 (see section 3.1). Density estimates were derived using hybrid mixture models in spatially explicit capture recapture analyses. Estimated habitat mask area refers to the surveyed area within which hair tubes were located in each study site, including a 2,000m buffer of suitable habitat. Randomly selected sites are 1-13 and 16; preselected study sites are 14-15 and 17-19. SE is standard error; LCL is lower 95% confidence interval and UCL is upper 95% confidence interval.

| Site | Estimated Habitat Mask (ha) | Density | SE | 95% LCL | 95%UCL |
|---|---|---|---|---|---|
| 1 | 1,462 | 0.75 | 0.21 | 0.44 | 1.29 |
| 2 | 1,908 | 0.97 | 0.24 | 0.60 | 1.56 |
| 3 | 2,607 | 0.60 | 0.15 | 0.37 | 0.99 |
| 4 | 4,269 | 0.52 | 0.13 | 0.32 | 0.83 |
| 5 | 2,399 | 0.46 | 0.15 | 0.24 | 0.86 |
| 6 | 1,435 | 0.89 | 0.27 | 0.50 | 1.59 |
| 7 | 1,652 | 0.00 | - | - | - |
| 8 | 1,792 | 0.93 | 0.17 | 0.64 | 1.32 |
| 9 | 1,832 | 0.54 | 0.14 | 0.32 | 0.88 |
| 10 | 2,218 | 0.72 | 0.18 | 0.44 | 1.16 |
| 11 | 2,099 | 0.12 | 0.09 | 0.03 | 0.45 |
| 12 | 2,108 | 0.25 | 0.14 | 0.09 | 0.68 |
| 13 | 3,211 | 0.50 | 0.15 | 0.28 | 0.87 |
| 14 | 1,141 | 4.29 | 1.72 | 2.01 | 9.17 |
| 15 | 1,849 | 2.12 | 1.06 | 0.83 | 5.37 |
| 16 | 1,031 | 2.60 | 0.56 | 1.71 | 3.95 |
| 17 | 1,564 | 2.51 | 1.43 | 0.88 | 7.11 |
| 18 | | | | | |
| 19 | 1,464 | 0.57 | 0.28 | 0.22 | 1.44 |
| Total | 36,041 | | | | |

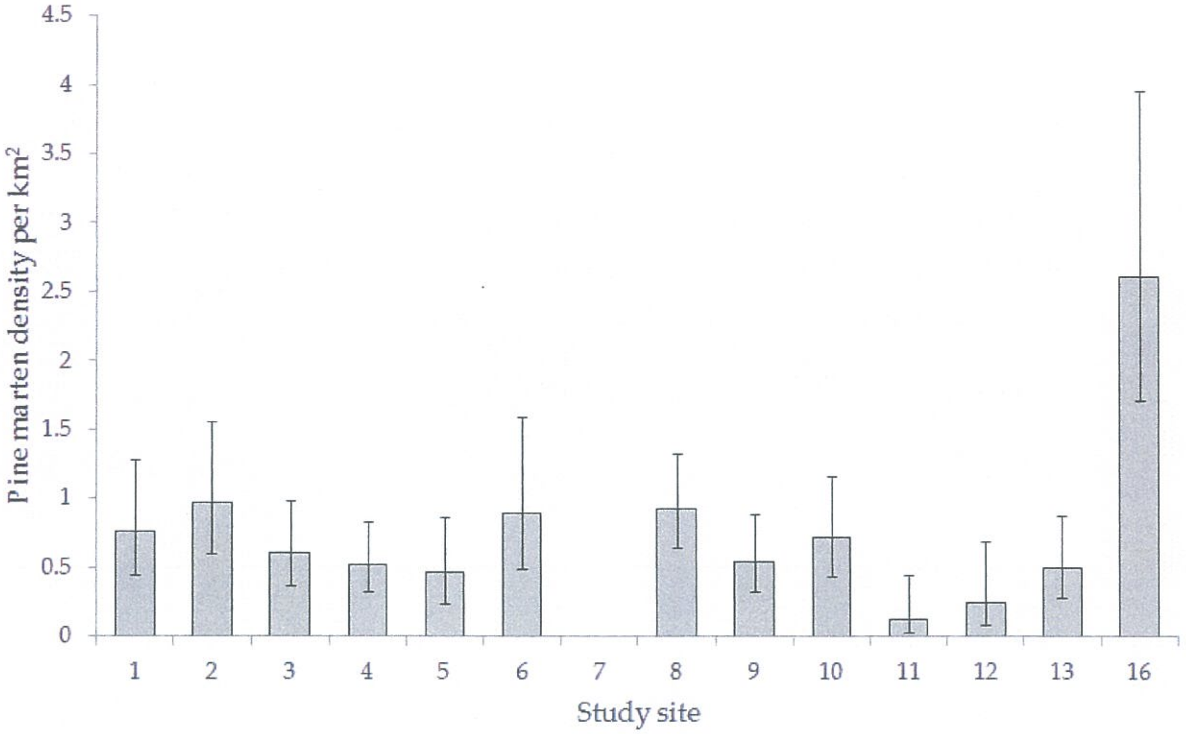


Figure 4. Variation in pine marten density across random study sites in Ireland. 95% CI for each site are indicated by error bars. Densities were estimated with the most parsimonious hybrid mixture models using spatially explicit capture recapture models.

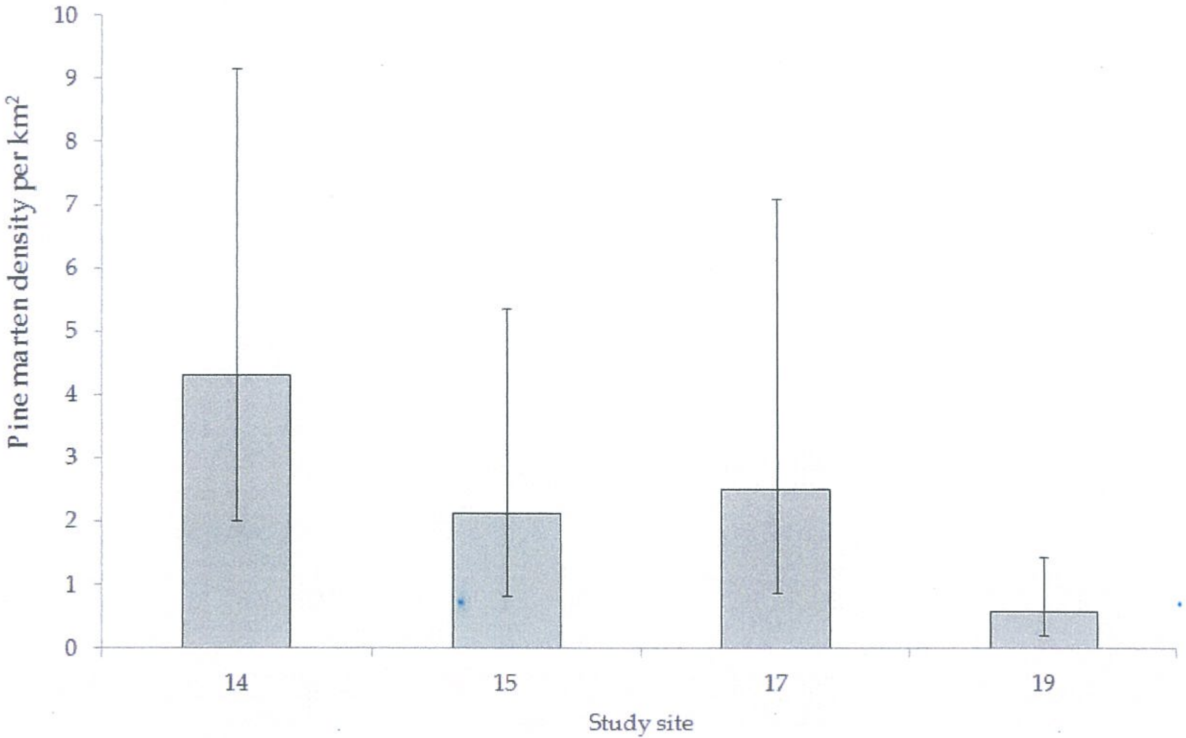


Figure 5. Variation in pine marten density across preselected study sites in Ireland. 95% CI for each site are indicated by error bars. Densities were estimated with the most parsimonious hybrid mixture models using spatially explicit capture recapture models.

Table 5. Estimation of pine marten abundance in each individual study site using CAPWIRE. Data were analysed using a Two Innate Rates Mode (TIRM) as recommended by Miller *et al.* (2005). Site locations given in Figure 1; MNA, Minimum Number Alive, number of unique genotypes detected; N, CAPWIRE population abundance estimate. The percentage of frequently captured individuals is given. (na, CAPWIRE analysis not carried out as sample size too low; *sites where recapture rate ≥2.5, see discussion). "Random" represents pooled data for the 14 randomly selected study sites.

| Site code | Sample number | MNA | Recapture rate | N | 95% CI | | Frequently captured |
|---|---|---|---|---|---|---|---|
| 1 | 10 | 6 | 1.67 | 12 | 6 | 30 | 17% |
| 2* | 27 | 9 | 3.00 | 9 | 9 | 9 | 44% |
| 3 | 18 | 8 | 2.25 | 12 | 8 | 21 | 25% |
| 4 | 20 | 10 | 2.00 | 19 | 10 | 32 | 11% |
| 5* | 16 | 5 | 3.20 | 6 | 5 | 10 | 17% |
| 6 | 11 | 6 | 1.83 | 7 | 6 | 10 | 43% |
| 7 | 0 | 0 | na | na | na | na | na |
| 8 | 20 | 11 | 1.82 | 27 | 11 | 44 | 7% |
| 9* | 15 | 6 | 2.50 | 6 | 6 | 6 | 67% |
| 10* | 22 | 8 | 2.75 | 8 | 8 | 8 | 38% |
| 11 | 2 | 1 | na | na | na | na | na |
| 12 | 2 | 2 | na | na | na | na | na |
| 13 | 16 | 7 | 2.29 | 11 | 7 | 18 | 18% |
| 14 | 31 | 19 | 1.63 | 39 | 21 | 61 | 18% |
| 15* | 21 | 8 | 2.63 | 11 | 8 | 18 | 9% |
| 16* | 38 | 14 | 2.71 | 19 | 14 | 26 | 32% |
| 17 | 11 | 7 | 1.57 | 10 | 7 | 24 | 30% |
| 18 | 4 | 3 | na | na | na | na | na |
| 19 | 9 | 4 | 2.25 | 5 | 4 | 9 | 20% |
| Random | 217 | 93 | 2.33 | 148 | 119 | 165 | 22% |

## 3.4 A national population abundance of pine marten

To estimate a national population abundance of pine marten based on the survey data in the current study, all capture data from the 14 randomly selected study sites (Sites 1-13 and 16) were pooled to estimate an average pine marten density across these study sites. This dataset consisted of 93 individual pine marten captured 217 times. This resultant mean density estimate was then combined with data on the current distribution of pine marten in Ireland and the amount of forested habitat within that distribution.

Using this approach and running a series of candidate models in secr, it was determined that a model specifying a sex and site specific detection effects on capture probability and sex effects on spatial scale was the best model (AICc 1479.68; Table 3). This provided a mean pine marten density estimate across the randomly selected study sites of 0.64 (95% CI 0.49 - 0.81) pine marten per km$^2$ of forest habitat. The habitat mask for this analysis was approximately 30,023ha of forest habitat. In CAPWIRE, the estimated total pine marten population abundance across the 14 randomly selected study sites was 148 (95% CI 116-165). Combining the mean density estimate across the 14 randomly selected study sites with current pine marten distribution in Ireland, it was estimated that 475,565ha of forest habitat existed within current pine marten range in Ireland. Combining this data with mean density estimates, the estimated current pine marten population in Ireland was estimated at 3,043 (95% CI 2,330 – 3,852) individuals.

# 4. Discussion

## 4.1 Genetic analysis

The overall yield of samples in hair tubes was 63%. Only 11 of the samples (3%) did not yield pine marten DNA, only one of these could not be identified and that was a poor hair sample with only 2 hairs. The remaining 10 samples were dog (4), cat (1) or stoat (5). The dog and cat samples may be assumed to be environmental contamination, a low rate considering the large number of patches manufactured for the survey. It is worth noting that four of the five stoat samples were in site 3 and were collected from two groups of tubes 6.7km apart. Sex testing was slightly less successful (94% of pine marten samples), which reflects the lower concentration of X and Y chromosomal DNA. Individual study sites had a range of sex ratios reflecting the low numbers of individuals concerned, and the overall sex ratio had a small male bias (60% of samples) consistent with larger male territories and less risk averse behaviour. Genotyping was highly successful with 89% of pine marten samples yielding a good genotype at the main 6 loci. This high success rate is the result of considerable method development at WIT.

## 4.2 Pine marten density in Ireland

This is the first study that has explicitly aimed to determine variation in pine marten density across multiple sites throughout Ireland and produce a national population abundance estimate for pine marten. Such information is critical in terms of the conservation and management of protected and important species such as pine marten, and provides the basis for part fulfillment of national and international conservation obligations with reference to this species. The estimated site specific densities for pine marten ranged from 0 to 2.60 individuals per km$^2$ of forest habitat in randomly selected sites, however, the majority of study sites had density estimates of less than 1 pine marten per km$^2$ of forested habitat. In preselected study sites density ranged from 0.57 to 4.29 pine marten per km$^2$. The majority of current density estimates are within the ranges reported for pine marten in Ireland (Sheehy *et al.* 2014; O'Mahony *et al.* 2015) and for the species across its range (Zalewski *et al.* 1995; Manzo *et al.* 2012; Balestrieri *et al.* 2016). Therefore, although comparisons between studies should be treated cautiously due to differing objectives, methods and analyses, as a general inference, pine marten densities in Ireland are not exceptional in terms of the range that exists for the species in other parts of its global distribution. Pine marten, like other members of the genus *Martes*, and carnivores in general, typically exist in low density populations with the range of densities for pine marten across Europe from 0.03 to 1.75 per km$^2$ (Zalewski & Jędrzejewski 2006), which correspond well with the majority of the estimates in the current study. Pine marten ecological and behavioral traits such as their solitary nature, low reproductive output, territorial system of social organisation and variable home range overlap with other individuals, combined with their relative habitat specialism for forests and woodlands, which is a limited resource in Ireland, are indicative factors that generally promote the existence of low densities within this species across their range. Areas of high pine marten density were highly localised and rare in the current study.

Although one of the principal objectives of the current study was to determine variation in pine marten density across sites in Ireland, the sample size of individual pine marten and the number of captures was low in most of the sites surveyed. Only 21% (4/19) of study sites in the full dataset had minimum number alive estimates of 10 or more pine marten, and out of the 14 random site dataset, only 21.42% of sites (3/14) had a minimum of 10 individual pine marten. As each study site was surveyed for one month and included several hundred, if not thousands, of hectares of forest habitat per site, and given that the non-invasive technique used in the study has been proven to work in Ireland (O'Mahony *et al.* 2015; see Table 1), we can be confident that these estimates of low pine marten numbers are robust. Traditionally, in capture recapture studies, sample sizes of individuals of less than 20 may be too small for reliable density estimation (Otis *et al* 1978; White et al. 1982). However, spatially explicit capture recapture techniques can produce more reliable density estimates with small sample sizes of individuals (Borchers & Efford 2008; Gardner *et al.* 2010; O'Brien & Kinnaird 2011; Sollman *et al.* 2011).

Where small numbers of individuals exist within a population, limiting the complexity of implemented secr-based candidate models is advisable (Royle *et al.* 2009; O'Brien & Kinnaird 2011), and was the approach undertaken in this study. Similarly, CAPWIRE that was used to estimate abundance in the current study was originally designed specifically for small populations (Miller *et al.* 2005). Estimated confidence intervals associated with density estimates, in most cases overlapped to such an extent that it was not possible to statistically compare density estimates across sites. High pine marten densities (i.e. >2 per km$^2$ in the current study) were rare, having occurred in a single random study site, and in 3 study sites within the preselected study sites (i.e. 22.22% of all sites where density could be determined). Potential factors that may have influenced such comparatively high density estimates in preselected sites may include that these sites were in some of most intact remnants of semi-natural forest habitat in Ireland, 3 of the sites were protected either as National Parks or nature reserves and had associated long-term forest cover. Specific research investigating factors influencing the occurrence of high density pine marten populations in Ireland would be required to determine any causal processes influencing variation in pine marten density in Ireland.

This study combined a randomised survey design to estimate site specific and mean density estimates across sites, with current knowledge on pine marten distribution and the extent of habitat occupied, to derive a national population abundance estimate for pine marten. Potential limitations of this methodology have been discussed in section 2.4. Evidence based extrapolation from multi-scale density and abundance studies to produce larger scale regional or national population abundance of species is widely reported in the literature (Erb & Sampson, 2009; Frary *et al.* 2011; O'Mahony *et al.* 2012; Fechter & Storch, 2014; Humm *et al.* 2015; Gervasi *et al.* 2016). Without major funding initiatives to support research studies, these methods are the only realistic means of obtaining such data. The current study was carried out in the range of habitat types within which pine marten occur in Ireland from semi-natural broadleaf forests to non-native coniferous plantations. A relatively large forest area was surveyed to establish density estimates, which were then scaled up to national abundance using current distribution data and estimates of habitat area occupied. This study represents the largest-scale direct assessment of pine marten density in Ireland, and probably across the species global distribution. The combined dataset from the 14 randomly selected sites consisted of 93 individual pine marten, captured 217 times, a recapture rate of 2.33 across the individuals identified in the study. This compares well with studies involving capture recapture estimation for related species such as the American marten and fisher (Mowat & Paetkau 2002; Sweitzer *et al.* 2015) and provided reliable estimation of pine marten density across the study sites surveyed in this project. The current study has produced the most reliable density and abundance estimates hitherto for pine marten in Ireland.

The national pine marten abundance estimate in the current study of 3,043 (95% CI 2,330 – 3,852) individuals, is as far as we are aware, the first directed large-scale pine marten density and abundance research study in any country subject to the reporting requirements of the EC Habitats Directive. In other jurisdictions that have been subject to conservation assessments for pine marten, national abundance estimates for pine marten have been largely achieved using limited data sources and expert opinion (see http://bd.eionet.europa.eu). For example, in the UK the pine marten population has been assessed as similar to that in Ireland at approximately 3,800 individuals, but the majority of that population exists within Scotland where pine marten densities can range from 0.12 to 0.58 per $km^2$ (Croose *et al.* 2016; and references therein).. The current study may provide a framework for more robust estimates of this species in other jurisdictions. In comparison with other terrestrial mammal populations in Ireland for which data on national population abundance are available such as the Irish hare (up to 1,000,000; Reid *et al.* 2007), badger (84,000; Sleeman *et al.* 2009) and even European otters (up to 10,000 females only; Reid *et al.* 2013), it is clear that pine marten are amongst the rarest of Ireland's wildlife populations, despite any potential increases in the species distribution and abundance over the last 10 years.

## 4.3 Conservation status of pine marten in Ireland

### 4.3.1 *Range*

The most recent distribution and range assessment for pine marten in Ireland is from the period 2005-2007 (O'Mahony *et al.* 2012) and no further national range assessments for pine marten have been undertaken since that survey. Given that a period of 10 years has elapsed since the last national distribution survey for pine marten, a new assessment would be prudent as reliable knowledge on the pine marten distribution in Ireland has been a key component on national abundance estimates for the conservation assessment. In the absence of national-scale directed research studies on pine marten distribution in Ireland, the National Biodiversity Data Centre has used an online Mammal Atlas project that involves compiling existing and historic datasets on pine martens recorded from varied studies in Ireland, together with a proactive citizen science type approach to determine current pine marten distribution (Lysaght & Marnell, 2016). Although comparisons between the field-based distribution study of O'Mahony *et al.* (2012) and that of the Mammal Atlas should be treated with caution, at the very least it is possible to deduce that current pine marten range in Ireland has remained stable, if not marginally increased, in the intervening years since the previous conservation assessment. A field-based distribution survey on current pine marten distribution in Ireland is required to determine the current range of pine marten, particularly in the southwest of Ireland where pine marten distribution is apparently very fragmented.

### 4.3.2 *Population*

There have been relatively few ecological studies on pine marten in Ireland and only a single national population abundance assessment for the species. O'Mahony *et al.* (2012) utilised data on the known distribution of pine marten in Ireland (derived from data during the 2005-07 distribution study) and combined that with data on average pine marten home range size (O'Mahony 2014), to estimate the first preliminary national abundance of pine marten in Ireland. That approach. explicitly acknowledged the caveats and data limitations that this preliminary estimation method was based on (O'Mahony *et al.* 2012). The national population estimate of pine marten in Ireland between 2005 and 2007 was estimated at 2,740 individuals (95% CI 1,350-4,330) (O'Mahony *et al.* 2012). The current study was designed specifically to estimate site specific pine marten density and abundance estimates, dependent on adequate sample sizes of individuals and capture events within study sites, which then could be used to produce average density estimates across surveyed sites, to reliably estimate the range of pine marten densities that may exist in Ireland.

The current study has produced a mean pine marten density estimate of 0.64 (95% CI 0.49 - 0.81) per $km^2$ of forest habitat from 14 study sites in approximately 30,133ha of forest, including a 2,000m habitat buffer. Combining this with current pine marten distribution data and forest habitat availability within that distribution (see methods section) the current national pine marten abundance estimate for Ireland is 3,043 (95% CI 2,330 – 3,852). Acknowledging methodological constraints associated with this estimate, the current population abundance of pine marten in Ireland is in the range of the low thousands of individuals. Determining the significance of any change in estimated population abundance since the previous national population estimate (O'Mahony *et al.* 2012) should be treated cautiously, as the data used for the basis of assessments were not directly comparable. The previous study considered a breeding population assessment (i.e. pine marten with established territories), whereas this current study was likely to include estimates of sub-adults between 6 and 12 months. However, if any such comparisons were made, then it is obvious that estimated mean abundances and confidence intervals overlap, indicating no significant change. It is suggested that this current study reinforces the abundance of that determined from O'Mahony *et al.* (2012) and that the current pine marten population in Ireland exists in the low thousands of individuals. On the basis of the precautionary principle, it is suggested that the population has at least remained relatively stable over the last 10 years.

### 4.3.3 *Habitat*

As pine marten rely on forest and woodland cover throughout their range, the availability of this habitat type is critical to the establishment of the species in areas and for range expansion where the species has been historically extirpated. The Irish government is targeting an increase in forest cover in Ireland by 15,000ha per year between 2016 and 2046, to provide an estimated 18% landcover of forestry by 2050 (DAFM 2014). Currently, the forest extent in Ireland is estimated at 653,980ha or 9.5% of landcover, and is one of the least forested countries in Europe. Irrespective of whether or not these targets will be achieved, significant changes have occurred in the type and extent of forest that is being planted in Ireland. Large-scale new plantations are now discouraged to favour small, more diverse and fragmented forestry by private landowners. This is creating an even more highly fragmented habitat for pine marten, but perhaps more connected in terms of forest availability, with unknown consequences for the species' biology and ecology. However, forest cover is likely to increase and not decrease into the future so habitat availability should be sufficient for at least maintaining the current population of pine marten in Ireland, should potential pressures and threats to the population not increase.

#### 4.3.4 Pressures and threats

Conservation strategies and management objectives for pine marten should be developed to take account of any potential increase in illegal persecution and conflicts arising from the re-establishment of pine marten in previously extirpated areas (O'Mahony *et al.* 2012). Apart from a few important initiatives by the VWT and NPWS in informing householders and game owners on reducing potential conflict with pine marten, there has been little done to address these important issues. Over recent years there has been increasing negative and misconstrued media attention on this species, blaming it for poultry attacks and the killing or damaging of lambs and sheep in parts of Ireland, which have culminated in suggested reports that the species may attack children, and that a 'cull' must be undertaken in parts of Ireland where pine marten are 'out of control'. It is likely that the pine marten population in Ireland is currently being subject to illegal persecution in some regions, to an unknown extent. The future prospects of the species may be uncertain in the medium to long term given current levels of negative media attention, calls for control and the lack of a coordinated strategy to address any potential conflict issues. Pine marten are a species with a low reproductive output and high population turnover, similar to other species (Buskirk & Ruggiero, 1994), and are therefore extremely susceptible to population control, whether illegal or legal.

Other factors that may impact on the pine marten population in Ireland include road traffic mortality; shooting, poisoning, trapping, predator control schemes and forest management. With regard to the latter, the main concerns are that the majority of the forest habitat resource in Ireland is managed for commercial gain and that current forest policy favours small-scale, fragmented forest establishment, which may be unsuitable in terms of pine marten socio-spatial ecology (see O'Mahony 2014). Overall, given the current state of knowledge of pine marten population abundance and distribution in Ireland, the future prospects in the short term (i.e. 5 years) are deemed to be adequate. However, if serious efforts are not implemented to address an increasingly vociferous lobby against the species through evidenced based research studies and the development of any associated mitigation measures, this could quickly be reversed.

## 4.4 Recommendations for pine marten monitoring in Ireland

Based on the results of this study the following recommendations are provided for the future monitoring of pine marten in Ireland:

1. Conduct a field-based distribution and range assessment for pine marten in Ireland as the previous data is now 10 years old. This should be particularly targeted at the edge of known pine marten distribution in Ireland to assess any continued range expansion and focus on the south and southwest of Ireland where pine marten distribution appears to be reduced and fragmented.
2. The results of this study indicated that in the majority of individual study sites pine marten numbers and captures were generally low, with indications that pine martens may still be absent from some sites within their range, even where large areas of suitable habitat occur. Although statistical density estimation techniques such as secr and CAPWIRE used in the study are generally robust to low sample sizes, increased samples sizes in density estimation research are preferred. Future research that focuses on pine marten density estimation in Ireland should consider adopting a landscape scale approach to study area identification such that it is likely to be sufficient to contain at least 15-20 individual pine marten. Based on evidence from the current study on mean pine marten density of 0.64 (95% CI 0.49 - 0.81), a minimum potential study area size of 2,000 to 3,000 ha of forest habitat could be a useful indicator, as used in O'Mahony *et al.* (2015). That is of course unless *a priori* rationale exists for suspecting high pine marten density in smaller sites.
3. This density estimation research project should be repeated at intervals of 5-7 years, particularly in the 14 randomly selected study sites, to ascertain any changes in site specific and mean density and abundance estimates across sites, which may have occurred within the population.
4. As advocated previously and throughout this report, there needs to be a commitment to funding of research studies into the general ecology of pine marten in Ireland. This will increase our knowledge of the species' role and function in the environment, which can specifically help address issues of potential conflict with people and inform relevant mitigation to reduce any such scenarios. An educational and advisory protocol should also be instigated in areas where current conflict has been identified.

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Forestry Commission

Research Report

# Recreational use of forests and disturbance of wildlife



Forest Research

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# Recreational use of forests and disturbance of wildlife

## A literature review

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# Contents

# Summary

## Background and objectives

- The pursuit of recreational activities in UK forests is increasingly popular and provides many social and economic benefits. However, such activities can have significant impacts on the natural environment and wildlife. Land managers, especially in the public sector, have to balance the delivery of social and economic benefits with the requirement to promote nature conservation.
- This review provides an overview of wildlife and habitat disturbance issues and impacts, focusing on recreational activities undertaken in UK forests including walking and hiking, cycling and mountain biking, off-roading, horse riding, camping and nature watching.
- In this review, disturbance includes any phenomena that can impact directly on wildlife or wildlife populations (such as causing 'flight'), or that can impact indirectly (such soil erosion and other habitat changes).

## Extent of evidence

- This review has identified only five published studies of recreational disturbance which draw on primary research conducted in UK forests. A search of primarily peer-reviewed literature (published mainly between 1990 and 2010) identified more than 450 generally relevant journal articles, book chapters, dissertations and reports.
- A large proportion of the literature focuses on walking, and on impacts on soils, vegetation and birdlife. Birds are the subject of 19 of the 26 UK studies (published since 1990), with seemingly few published studies on British mammals, invertebrates, reptiles or amphibians.

## Impacts of recreational activities on wildlife

- The literature tends to group activities together in categories that describe the physical characteristics of disturbance, such as 'trampling'. This masks considerable likely variation between recreational users, habitat and wildlife.
- Five key generalisations can be made about the impacts of recreation on wildlife (summarised by Cole, 2004): (i) Impact is inevitable with repetitive use; (ii) Impact occurs rapidly, while recovery occurs more slowly; (iii) Impacts increase more as a result of new places being disturbed than from further deterioration of already impacted sites; (iv) The magnitude of impact depends on frequency, type and spatial distribution of use as well as environmental conditions; (v) The relationship between amount of use and level of impact is usually non-linear.
- There is a substantial body of literature on disturbance caused by walking, the most popular recreational activity in UK woods and forests. Most relates to damage through trampling, including vegetation damage/abrasion, reduced vegetation cover, reduced plant species density, decreased leaf litter biomass, and increased trail width and depth. These impacts decrease with the distance from trails.
- There is a considerable amount of research on how walking can induce an anti-predator response in wildlife ('flight'). Much of this is related to ground-nesting birds (particularly waterbirds) with only a few studies available of non-bird species. Overall, there is little available evidence to suggest that the flight response to walking has any long-term negative impacts.
- Cycling and mountain biking has expanded rapidly in recent years. Many studies focus on impacts of this activity on the environment through erosion and trampling of vegetation. Some studies show that mountain biking does cause

individual animals to use habitat differently and increases flight response. However, no long-term negative impacts have been identified and some literature suggests the there are no or few impacts on some species.

- Horse riding can affect habitat though soil compaction, trampling of vegetation, damage to surface litter and vegetation, and erosion. Most evidence suggests that horse riding occurs primarily on specifically designed bridleways, but some studies report the use of shortcuts or veering off trails to avoid obstacles.

- Evidence from the USA shows that off-road driving is one of the fastest growing recreational activities. Impacts can include compaction and erosion of soil, and animal death or injury through collisions. Indirect impacts include noise leading to abandonment of territory, raised energy consumption and increased risk of predation. Events such as car rallies may lead to some nest abandonment in birds of prey, while vehicle tracks can fragment habitats and block movements of small mammals, amphibians and invertebrates.

- Camping, nature watching and picnicking can induce behaviour change in animals which are attracted to food sources left by people. Further impacts include littering, vandalism and fires. Nature watching can be particularly intrusive, involving viewing, touching, feeding, or photographing wildlife.

- Some recreational activities can introduce harmful species or pathogens. Footwear, vehicles and bicycle tyres can carry these into forests. Horses can also potentially contribute to the spread of invasive or non-native plants or pathogens on their hooves, coat, or via their digestive tract, although most studies concur that horses are not a substantial cause of biological invasion.

- Many studies reported limited long-term impacts, although this depends on tolerance levels, and habitat variability such as soil and climate.

## Recreational users' perspectives

- Few studies consider how users perceive their own and others' impacts on wildlife. There may be links between recreational activities, preferred places to visit, and visitor attitudes and behaviour; however, debate exists around whether participation in outdoor recreation increases pro-environment behaviour. Generally, users have little awareness of their impacts on wildlife and hold others responsible for negative impacts.

## Managing impacts

- Only a few studies systematically address management options although many provide recommendations. Management actions can include creating new recreation areas, physical and natural barriers or screens, track alterations, temporal restrictions, information or warning signs, trail maintenance, habitat restoration, impact surveys, buffer zones or minimum approach distances. Education and social marketing approaches are also management options. The effectiveness of management actions is often poorly understood.

- There are three main categories of access restriction: buffer zones, time and site restrictions, and visual screens, all of which require some level of spatial planning.

- Social marketing involves understanding the 'customer', their needs, expectations and motivations, how they currently behave, and ways to influence this behaviour.

- Recommendations for visitor 'education' are widespread although wider literature suggests a weak relationship between information, intention and actual behaviour. There is nevertheless a substantial body of work investigating effective education.

- 'Low-impact' interpretation strategies focus on encouraging appropriate behaviour. Messages that provide a rationale for recommended behaviour are considered more effective than statements of how to minimise impact.

## Challenges and research gaps

- Further information on the social dimensions of disturbance is critical. Research into the social and cultural differences between recreationists, how information is understood and acted upon, and attitudes towards impacts is very sparse. Little is known about how social and cultural norms affect recreationists' behaviour, nor how to monitor the effectiveness of management or governance mechanisms.

- We identified no studies that weigh the social benefits of public access and recreation directly against potential wildlife disturbance, although this is an overriding need for managers. More research is needed to understand the balance between positive and negative human - wildlife interactions, and to develop effective tools to help managers assess them.

- Little progress has been made in determining socially acceptable levels of impact, or the acceptability and effectiveness of various management options. More examples are needed of what management actions work and are acceptable.

- There is an compelling need for interdisciplinary studies that link ecological impact studies on wildlife with social data around recreational users. We suggest that a wide range of species and forest types are studied, not just those which have designated protection.

# Introduction

The pursuit of outdoor recreational activities in forests is increasing in popularity and can have substantial societal benefits including improved mental and physical health and tourism revenue (Clawson, 1985; Cordell, Betz and Green, 2002; Jensen and Koch, 2004; Martin, 2008). However, such activities can also have significant impacts, both negative and positive, upon the natural environment and its components – soil, vegetation, wildlife and water. These impacts and the associated threat of environmental degradation have given rise to a large body of literature including the field of recreation ecology (Liddle, 1997; Hammitt and Cole, 1998; Newsome, Moore and Dowling, 2001). This literature aims to inform site and visitor management through biological investigation of the relationships between specific activities and impacts, and assessment of ecologically acceptable levels of environmental change, for example 'Limits of Acceptable Change' (LAC) (Stankey *et al.*, 1985; McCool, 1996). Whole textbooks are dedicated to describing and managing these issues (see, for example, Knight and Gutzwiller, 1995), with a particular recent focus on 'ecotourism' (Buckley, 2004).

Public land managers are charged with concurrently delivering broad ecological, social and economic benefits from the land under their control, which requires that they must, among other things, balance the impacts of public access for recreation (and the capture of the associated benefits) with the requirement to conserve biological diversity (Kazmierow, Hickling and Booth, 2000). During consultation workshops in November 2009 (Marzano and Dandy, 2010) Forestry Commission colleagues expressed the need for up-to-date and specific information regarding the disturbance caused to wildlife by recreational activities in UK forests. This was considered necessary as it is felt that debates over the issue of disturbance were in danger of becoming increasingly generic with broad assumptions that all recreational activities had significant negative impacts on wildlife.

Our objective in this document is not to provide an exhaustive review of the recreation ecology and other literature pertaining to forests. To do so would require a full-length textbook, of which there are various available (cited above and in the references). Instead our focus here is to provide:

- An overview of disturbance issues and impacts relevant to recreational activities in UK forests and woodlands.
- A detailed guide to the literature on UK forests and species found in forests.
- Key references for readers to draw on if further information is needed.

Additionally, our approach differs from that adopted most commonly in the recreation ecology literature by focusing the synthesis on the recreational activities themselves, rather than particular species, habitats or taxa. We collate the sparse information relating to the social dimensions of recreational impacts from within the primarily ecological studies with a particular focus on key types of recreational activity including walking and hiking, cycling and mountain biking, off-roading and horse riding with further information on camping, nature watching and other outdoor activities. The key questions we asked were:

1. What is the level and range of disturbance impacts on flora and fauna from recreational activities?
2. Which social phenomena affect the type and scale of impacts (e.g. holiday periods, crowding, desire to go off path/trail)?
3. How do recreational users perceive their own and others' impacts on wildlife?
4. What affects recreational users' behaviour in natural areas (e.g. knowledge, understanding and perception of 'rules'; signs and interpretation)?

# Background

Wildlife* management systems have been identified by Decker *et al.* (2009, p. 316, citing Giles, 1978) as involving humans, wildlife (flora and fauna), habitats and their interactions. There has been a growing awareness in recent years that inclusion of social science perspectives in wildlife management is necessary, particularly where management actions are perceived to impact on people's values, identities and relationships with the environment (Marshall, White and Fischer, 2007). Wildlife management encompasses more than the 'label' suggests as processes, outputs and outcomes often have a value or benefit for humans (Decker *et al.*, 2009). Indeed, it has been recognised that successful solutions for management need to include a focus on both humans and wildlife if they are to be socially acceptable (Baruch-Mordo *et al.*, 2009). A focus on managing wildlife in woods and forests is important as these settings are particularly valued for recreation and tourism (Sun and Walsh, 1998). In the UK, an increase in outdoor recreation is already placing considerable pressure on some woodlands and forests (Littlemore and Barlow, 2005, see also McEvoy *et al.*, 2008). However, as Newsome, Moore and Dowling (2001) have pointed out in relation to 'wildlife tourism', there is little 'hard' data on wildlife responses to tourism or recreational activity (see also Blanc *et al.*, 2006; Rodger, Moore and Newsome, 2010).

## Disturbance

'Disturbance' can take myriad forms. Recreation ecology seemingly includes everything from small-scale pollution occurring completely independent of any direct response from wildlife, through to natural disasters and capture or killing of individual animals. A useful review by Blanc *et al.* (2006, p. 119) provides some definitions of disturbance. They note that the most commonly used definition is provided by the European Commission as 'any phenomenon that may cause a significant change in the dynamics of a population or the ecoethological characteristics of populations'. This review also includes non-direct impacts on flora and fauna such as impacts on the local environment, particularly soil erosion, compaction and trampling. Disturbance can further be divided into natural events and human-induced disturbances. Threatened and endangered species are considered to be particularly vulnerable to disturbance by outdoor recreation (George and Crooks, 2006 and references therein).

Animal behavioural responses to disturbance can be classified under avoidance, attraction and habituation (Newsome *et al.*, 2002). Liddle (1997) divides disturbance into three types. Type 1 disturbances are 'transient' where ephemeral activities cause animals to move, take flight or 'flush' for fear of predation. Type 2 disturbances are 'permanent' changes such as habitat destruction or modification. Trampling can cause this type of disturbance through, for example, the creation and degradation of trails and paths. Type 3 disturbances, according to Liddle, involve the capture or killing of wildlife. Hunting is the most obvious example of this type, but road traffic, off-road vehicle (ORV) driving, cycling, collecting non-timber forest products (NTFP) and walking can also have this impact on some flora and fauna. This classification is useful in some ways, but can hide considerable interesting variation and detail.

The broad range of disturbance may reflect the difficulties of directly relating recreational activities to impacts on wildlife as responses can differ, even within a species (Vaske, Decker and Manfredo, 1995). Knight and Cole (1995, p. 72-73) suggest there are four key features that influence the impact of recreational disturbance on wildlife: (1) the predictability of an activity and whether it is frequent enough to be considered non-threatening and thus requiring little response; (2) the frequency and magnitude of disturbance over and above thresholds where the activity becomes detrimental to wildlife; (3) timing, e.g. recreational disturbance is known to be damaging to wildlife during the breeding season but can also have serious effects at other times such as periods of feeding or resting; (4) locations where wildlife feels more secure.

Taylor and Knight (2003) emphasise the importance of differentiating between direct (e.g. approaching wildlife directly) and indirect (e.g. use of a road or trail nearby) disturbance and their impacts on wildlife. Several authors indicate that, generally, human presence and activities impact on large animals while smaller animals are more affected by habitat modification or other indirect impacts such as those associated with infrastructure (Hammitt and Cole, 1998; Newsome, Moore and Dowling, 2001). Plant communities are impacted more often by trampling, which reduces productivity and biomass (Newsome, *et al.*, 2002).

* The term 'wildlife' usually refers to non-domesticated members of the animal kingdom, but a broader definition also includes plants and other organisms (e.g. fungus).

## Recreational activities

Various public opinion surveys (e.g. Carter *et al.*, 2009; Forestry Commission, 2009) have shown that positive recreational experiences in the outdoors are associated with being able to see or hear wildlife (Newsome *et al.*, 2002). Woodlands and forests are important places for recreation but there are management implications related to the amount and type of activities that take place. In urban areas, for example, where greenspaces are often limited, forests can host large numbers of recreationalists with potentially significant knock-on effects on vegetation and wildlife (Heer, Rusterholz and Baur, 2003, p.212). Buckley (2004, p.212) highlights how wildlife habitat may be modified through 'tracks and trails; barriers; campsites and lodges; new sounds and smells; fire and weeds; provision or removal of food and water sources; and provision, removal or damage to refuges and breeding sites'.

A wide range of recreational activities take place in UK woodlands and forests, but repeated visitor surveys (www.forestry.gov.uk/statistics) show that four general categories of activity form the majority – walking (very often with dogs); cycling and mountain biking; nature watching and general visits to relax, play and/or picnic. Other activities include horse riding, ORV driving, hunting,** fishing, camping, paintballing, 'outward-bounds' activities (e.g. rope trailing and orienteering), NTFP collection, and large events (e.g. car rallies and concerts).

Disturbance by recreational activities can have major impacts on flora and fauna at individual, population and community level in the short and long term. It can have direct impacts such as causing 'flight' or modifying behaviour (foraging and reproduction) and indirect impacts such as habitat change and the introduction of pests, pathogens and weeds (Knight and Cole, 1995; Taylor and Knight, 2003; George and Crooks, 2006). A wide range of social factors affect why, when and where these acts occur, and therefore it is critical to recognise these as drivers of disturbance impacts.

## Scope of the review

This review identifies and discusses the literature relating to impacts caused by the disturbance of wildlife by recreational activities occurring in UK forests. We include literature relating both to direct impacts (e.g. flight, behaviour modification, injury and death) and indirect impacts - habitat change and the spread of pests, pathogens and weeds. Furthermore, it seeks to identify literature analysing why, when and where the impacts occur, including social scientific analysis.

** We do not cover hunting activities within this review. This is because although there is a considerable literature on hunting and associated disturbance of (and general impacts on) wildlife this is almost exclusively focused on non-British situations. British hunting patterns differ considerably in both scale and social structure from North American and other European patterns, thus making any comparisons problematic.

# Methods

This report is based on a review of primarily peer-reviewed published literature. We searched a number of databases including Web of Science, Google Scholar, Science Direct (Elsevier), CABE, tandfonline.com (Taylor & Francis) and our own EndNote databases to identify articles that contain key words or phrases focused around key outdoor activities that take place in forests (see Table 1). We focused on papers published between 1990 and 2010 to ensure that findings were likely to still be pertinent and applicable. For a summary and review of the literature prior to 1990, see Anderson and Radford, 1992. A few older references have been included where relevant, particularly to provide contextual information or to include seminal or otherwise important texts. From these searches we compiled a reference list using EndNote software. Further literature was identified from the citations and references of these texts. This analysis highlighted substantial gaps in the evidence and we have suggested areas for future research (see Discussion).

**Table 1** Search terms.

| Search term | and |
|---|---|
| wildlife / recreational disturbance / forests / | forests<br>forest roads<br>dog walking<br>cycling<br>skiing<br>birdwatching<br>hunting<br>biodiversity<br>fishing<br>boating<br>off-road vehicles<br>quad biking<br>car rallies<br>motocross<br>outdoor concerts<br>walking<br>camping<br>berry / ntfp collecting |
| wildlife | visitor behaviour<br>rope trails<br>human values<br>visitor management |
| outdoor concerts | noise |

# Results

Our research identified more than 450 papers, book chapters, student dissertations and other published materials relating specifically to the disturbance of wildlife by walking, mountain biking, horse riding, vehicle use, camping, nature watching and a few other relevant activities. Less than one-third relate directly to forests or woodlands, and only 26 report primary research done in any habitat in the UK in the last 20 years (see Table 2). We have identified only five published studies of recreational disturbance which draw on primary research conducted in UK forests or woodlands. This reveals a continuing lack of primary studies in these environments, noted previously by Anderson and Radford, 1992. The remaining studies provide either general or contextual evidence, and/or relate to studies of species found in UK forests but conducted elsewhere. A large proportion of the literature relates to walking (including with dogs) as an activity and to soils, vegetation and birdlife. Protected and 'wilderness' areas feature prominently. This central body of the literature, relating to ecological impacts, is described in the Impacts section on p.8, subdivided into stand-alone sections on the various recreational activities of relevance to UK forests (Figure 1).

Many studies refer generically to 'disturbance' or 'human disturbance', the definitions for which can include activities far wider than recreation. In particular, there is some literature on the disturbance of forest wildlife by harvesting or other forestry operations. We have sought to avoid this literature in our study, although we have included some references where the activities are similar to recreational activities (e.g. scientific 'investigator' disturbance on foot, which is similar to walking or hiking).

UK studies replicate the wider literature's bias towards and focus on walking, and on birds (especially ground-nesting species) and open habitats. Birds are the subject of 19 of the 26 UK studies, and the Dorset heaths and Cairngorms receive relatively more attention than other areas. British mammals are the subject of only one study, with seemingly very few published studies of recreational disturbance and British invertebrates, reptiles or amphibians.

There have been a number of reviews of recreational disturbance literature and many are freely available via the internet (see Table 3).

Management recommendations permeate the literature; however, only a limited literature exists which directly or systematically addresses the management options available. Evidence relating to how recreationists understand or perceive their own and others' impacts on wildlife is also very sparse. We discuss these areas of the literature in the sections on Recreational users' perspectives (p.22) and Managing impacts (p.24).

**Figure 1** Forest trails are suitable for various recreational activities.

**Table 2** UK studies of wildlife disturbance by recreational activities since 1990.

| First author | Date | Species/habitat | Method |
|---|---|---|---|
| Baines | 2007 | Black grouse, *Tetrao tetrix* | Radio-tagging, experimental disturbance and observations of people near birds during disturbance events |
| Barnard | 2003 | Beech woodland | Visitor numbers: automated traffic counter (ATC)<br>Perceptions of dogs and dog walkers: observation, questionnaires |
| Bayfield | 1996 | Mosses, grasses, forbs | 3 control sites, 2 seeded, 1 left unseeded. Direct visual recording of species cover and composition over 25 years |
| Beale | 2007 | Common guillemots, *Uria aalge*<br>Black-legged kittiwakes, *Rissa tridactyla* | Spatially explicit model colony with simulations of visitor distribution, testing model using empirical data |
| Bennett | 2009 | Barbastelle bats, *Barbastella barbastellus* | Simulation model SODA (simulation of disturbance activities) |
| Finney | 2005 | Golden plover, *Pluvialis apricaria* | Data collected 1986-98, survey of bird distribution; habitat data. Secondary path use data. Distance from path – index of disturbance. |
| Goss-Custard | 1993 | Various shorebirds/waders | 15 year study. Observations of human activities (dog walking, birdwatching, walking, casual and commercial shell-fishing) during bird counts |
| Haworth | 1990 | Various upland birds | Vegetation survey, breeding bird survey, discussions with gamekeepers, survey of features likely to disturb breeding birds |
| Johnson | 2000 | Ancient woodlands | |
| Keirle | 2004 | Study of footpath use | Mapped observation of users passing through specified area |
| Keller | 1991 | Eider ducklings, *Somateria mollissima* | |
| Langbein | 1992 | Red deer, *Cervus elaphus*<br>Fallow deer, *Dama dama* | Observation of habitat use, focal animal observation, with records of disturbance events |
| Langston | 2007 | European nightjar, *Caprimulgus europaeus* | Territory mapping, nest monitoring, vegetation measurements, observation of visitor path use |
| Liley | 2003 | European nightjar, *Caprimulgus europaeus* | Spatial integration of existing datasets: heathland survey, national and local nightjar survey, aerial photographs of developed land and postcode data |
| Littlemore | 2001 | (Urban fringe) Woodland ground flora and soils | Controlled experimental trampling |
| Mallord | 2007a | Woodlark, *Lullula arborea* | Nest location, ringing of chicks, observation |
| Mallord | 2007b | Woodlark, *Lullula arborea* | Territory mapping and habitat suitability, record of visitors along existing access routes at site level, no. of disturbance events within sites |
| Mayer-Gross | 1997 | Passerines | Data from 1960-61. Record of nests at nest-building stage and exposure of nest, mimicking behaviour of nest recorder, and vegetation recording |
| Murison | 2002 | Nightjar, *Caprimulgus europaeus* | Mapping of nightjar territory and nests, observation of nightjar breeding behaviour, postcode data |
| Pearce-Higgins | 2007 | Golden plovers, *Pluvialis apricaria*<br>Dunlin, *Calidris alpina* | Bird survey, nest search, radio-telemetry, visitor counts (data from 1980) |
| Ruddock | 2007 | Various bird species | Literature review, questionnaire survey to elicit expert opinion |
| Summers | 2004 | Capercaillies, *Tetrao urogallus* | |
| Summers | 2007 | Capercaillies, *Tetrao urogallus* | Search for capercaillie dropping, presence of raptors, wind and temperature measurements, questionnaire data from recreational users |
| Taylor | 2007 | Stone-curlews, *Burhinus oedicnemus* | Observation of breeding sites, routes followed by 'potential disturbing agents' mapped onto aerial photographs |
| Watson | 2004 | Ptarmigan, *Lagopus mutus* | Bird counts, territory census |
| Whitfield | 2007 | Goldon eagles, *Aguila chrysaetos* | Based on published datasets: census of golden eagles, counts of red deer, sheep numbers, estimations of changes in forest cover, records of illegal poisoning and persecution, spatial association between Munros (and hillwalkers) and eagle territory |

| Study location | Recreational activity | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Walking | Dog walking | Nature watching | Camping | Biking | Vehicles | Horse riding | Skiing | General | Other |
| England (North Pennines) | | | | | | | | | ■ | |
| England (Burnham Beeches NNR, Bucks) | | ■ | | | | | | | | |
| Scotland (Cairngorm) | | | | | | | | ■ | | |
| Scotland | | | | | | | | | ■ | |
| England (South West) | | | | | | | | | ■ | |
| England (Pennine Way) | ■ | | | | | | | | | |
| England (River Exe estuary) | ■ | ■ | ■ | | | | | | | |
| England (South Pennines) | | | | | | | | | ■ | |
| England (New Forest) | | | | ■ | | | | | | |
| Wales (Cwm Idwal, Snowdonia) | ■ | | | | | | | | | |
| Scotland (Ythan estuary) | ■ | ■ | | | | | | | | ■ |
| England (Richmond and Bushy parks, London) | | | | | | | | | ■ | |
| England (Dorset) | ■ | ■ | | | | | | | | |
| England (Dorset) | | | | | | | | | | ■ |
| England (Coventry, West Midlands) | ■ | | | | | | | | | |
| England (Dorset) | | | | | | | | | ■ | |
| England (Dorset) | ■ | ■ | | | ■ | | ■ | | | |
| England (Oxfordshire) | | | ■ | | | | | | | |
| England (Dorset) | | | | | | | | | ■ | |
| England (Peak District) | ■ | | | | | | | | | |
| Scotland | | | | | | | | | ■ | |
| Scotland (Abernethy Forest) | | | | | | | | | ■ | |
| Scotland (Glenmore and Abernethy Forests) | ■ | | | | ■ | ■ | | | ■ | |
| England | ■ | | | | | | | | | |
| Scotland (Cairngorm) | | | | | | | | ■ | | |
| Scotland | ■ | | | | | | | | | |

**Table 3** Reviews and bibliographies of disturbance to wildlife caused by recreational activities, since 1990.

| First author | Date | Title | Subject | Species/habitat |
|---|---|---|---|---|
| Carney | 1999 | A review of human disturbance effects on nesting colonial waterbirds | Human disturbance (investigators and visitors) | Waterbirds |
| Cessford | 1995 | Off-road impacts of mountain bikes: a review and discussion | Mountain biking | Various |
| Cole | 2004 | Impacts of hiking and camping on soils and vegetation: a review | Hiking<br>Camping | Soil<br>Vegetation<br>Wilderness areas |
| Dahlgren | 1992 | Human disturbances of waterfowl: an annotated bibliography | Human disturbance | Waterbirds |
| Knight | 1995 | Wildlife and recreationists: coexistence through management and research | Various (including walking, horse riding, nature viewing, and vehicles)<br>Hunting | Various |
| Lathrop | 2003 | Ecological impacts of mountain biking: a critical literature review | Mountain biking | Various |
| Leung | 2000 | Recreation impacts and management in wilderness: a state-of-knowledge review | Walking<br>Camping | Soil<br>Vegetation |
| Sidaway | 1990 | Birds and walkers: a review of existing research on access to the countryside and disturbance to birds | Walking | Birds |
| Sun | 1998 | Review of studies on environmental impacts of recreation and tourism in Australia | Various, including walking, camping and horse riding | Vegetation<br>Soils |
| Taylor | 2005 | Dogs, access and nature conservation | Dog walking | Birds |
| Tempel | 2008 | Understanding and managing backcountry recreation impacts on terrestrial wildlife: an annotated reading list | Backcountry recreation | Carnivores<br>Ungulates<br>Small mammals<br>Raptors<br>Birds<br>Reptiles<br>Invertebrates |
| York | 1994 | Recreational-boating disturbances of natural communities and wildlife: an annotated bibliography | Boating | Various |

## Impacts

This section provides an overview of the literature relating to the impacts of recreational activities on forests and forest species, with an emphasis, where possible, on the UK. It is subdivided into several stand-alone sections pertaining to specific activities, which can be read without reference to each other. Having said this, there are some general principles which are usefully identified prior to addressing each activity.

First, in the literature the impacts of various recreational activities are frequently categorised as 'trampling', that is mechanical pressure on soils, flora and fauna from feet, hooves or vehicle tyres. In this sense, the literature analyses the majority of impacts together. This contributes to the generally asocial nature of much recreational disturbance literature, excluding the values, perspectives and behaviour of the people involved (see the Impacts – physically similar, socially diverse section on p.30). Torn *et al.* state 'Trampling is the most prevalent impact of recreation and nature tourism.' (2009, p. 1427). Furthermore, much recreational activity occurs on or close to designated locations, such as car parks or campsites, and defined paths, tracks, roads or other 'trails'. Thus, in the same sense as 'trampling' above, impacts caused by different activities can commonly be considered together as 'trail' or 'site' impacts. For example, Thurston and Reader assert that 'Managers of natural areas consider recreational impacts along trails and on campsites to be their most common management problem.' (2001, p. 397).

Other work indicates environmental variables that can affect the magnitude of impacts from recreational disturbance including soil type, habitat structure and composition (e.g. shrub and tree cover), sensitivity of species, habituation of species to human presence and management measures currently in place. In his review, Cole (2004, p. 55) offers five key generalisations regarding the impacts of walking, although they are widely relevant to other forms of recreation. These are:

1. Impact is inevitable with repetitive use. Numerous studies have shown that even very low levels of repetitive use cause impact. Therefore, avoiding impact is not an option unless all recreation use is curtailed. Managers must decide on acceptable levels of impact and then implement actions capable of keeping use to these levels.
2. Impact occurs rapidly, while recovery occurs more slowly. This underscores the importance of proactive management, since it is much easier to avoid impact than to restore impacted sites. It also suggests that relatively pristine places should receive substantial management attention, in contrast to the common situation of focusing most resources in heavily used and impacted places. Finally, it indicates that rest-rotation of sites (periodically closing damaged sites, to allow recovery, before reopening them to use) is likely to be ineffective.
3. In many situations, impact increases more as a result of new places being disturbed than from the deterioration of places that have been disturbed for a long time. This also emphasises the need to be attentive to relatively pristine places and to focus attention on the spatial distribution of use. It suggests that periodic inventories of all impacted sites is often more important than monitoring change on a sample of established sites.
4. Magnitude of impact is a function of frequency of use, the type and behaviour of use, season of use, environmental conditions, and the spatial distribution of use. Therefore, the primary management tools involve manipulation of these factors.
5. The relationship between amount of use and amount of impact is usually curvilinear (asymptotic). This has numerous management implications and is also fundamental to many minimum impact educational messages. It suggests that it is best to concentrate use and impact in popular places and to disperse use and impact in relatively pristine places.

## Walking and hiking (including dog walking)

Walking is the most frequent and popular recreational activity conducted in natural areas such as forests and woods (Figure 2). It is certainly the most widely reported and recorded activity on land managed by the Forestry Commission (Watson and Ward, 2010). Hiking and walking have the potential, however, to disturb wildlife in a

**Figure 2** Forest roads are ideal for family walks.

number of ways including trampling, causing animal flight in response to noise and/or approach, habitat change or degradation through trail (path) and trailside management, use or pollution, and the introduction of invasive or otherwise harmful species or pathogens. Trampling associated with footpaths was the subject of much of the earliest systematic investigation in recreational ecology (e.g. Bayfield, 1971, 1973, 1979; Liddle, 1975) and Cole noted that of the approximately 1000 studies in recreational ecology conducted up until 2004 the 'majority have focused on the impacts of hiking and camping' (2004, p. 55) - particularly impacts on vegetation and soils. There exists, therefore, a very substantial quantity of information and data relating to the disturbance caused by walkers. Nevertheless, the vast majority of this evidence relates either to vegetation damage through trampling, or to flushing of ground-nesting birds (especially waterbirds) - with woodland environments and species receiving less attention.

In the UK, a high proportion of walkers using woods and forests are accompanied by dogs: Taylor *et al.* (2005) assert a figure of up to 50% in lowland areas, with fewer in upland areas (Figure 3). This can serve to increase (in some cases dramatically) the scale of disturbance (or 'sphere of influence', Taylor *et al.*, 2005). The impact of dogs has received widespread attention - although again primarily in relation to ground-nesting birds (although Miller, Knight and Miller, 2001 illustrated increased disturbance of mule deer by dogs), and in non-forest environments.

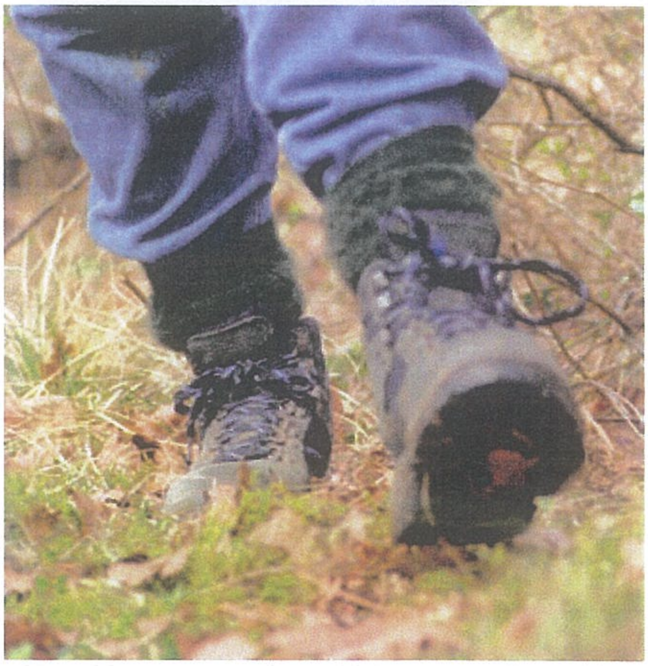
Walking in forests and other natural areas can potentially disturb wildlife, with three general categories of effect. These are: (i) habitat change; (ii) 'flight'; and (iii) the introduction of invasive species, pests or diseases.

**Figure 3** Dogs can increase the level of disturbance.

## Habitat change

Considerable evidence has shown that the impact of walkers' footfall on the ground can have significant trampling effects in forests - with various potential impacts on flora and fauna and habitat (Figure 4). These can include vegetation damage/abrasion, reduced plant/vegetation cover, reduced plant species density, decreased leaf litter biomass, organic soil removal and compaction, reduced plant genetic and species diversity, and increased trail width and depth (Kissling *et al.*, 2009; Roovers *et al.*, 2004; Rusterholz, Kissling and Baur, 2009; Torn *et al.*, 2009; Waltert, 2002; Weaver and Dale, 1978; Wimpey and Marion, 2010. For reviews see Leung and Marion (2000) and Cole (2004).

**Figure 4** Impact can have a serious effect on vegetation.



Recent studies have confirmed earlier findings (e.g. Bayfield, 1971, 1973) that trail characteristics can have a substantial affect on disturbance, for example trail 'roughness can cause hikers to widen trails by seeking out smoother trailside hiking surfaces' (Wimpey and Marion, 2010, p. 2035). However, impacts seemingly decrease with distance away from trails. Dale and Weaver (1974) noted that vegetation more than 2 m from a trail edge is not often affected.

## Indirect impact of habitat change

Impacts are not always negative. Davis' study of salamanders actually identified a beneficial relationship between trail presence and species success, noting that 'trails result in more microhabitats for salamanders around them.' (2007, p. 385). However, other analyses of human disturbance of reptiles describe some significant negative impacts; for example the removal and accelerated decay of woody debris vital for skinks (Hecnar and M'Closkey, 1998).

## Flight and behaviour change

A very substantial amount of research has focused upon measuring how and when walkers disturb wildlife through approaching them, and/or causing noise, which triggers, in essence, an anti-predator response of escape ('flight'). Within this literature there is once again, however, a very heavy focus upon birdlife (for reviews see Sidaway, 1990; Taylor *et al.*, 2005), which itself focuses substantially upon ground-nesting birds (for a 'systematic review' see Showler *et al.*, 2010) and disturbance by dogs accompanying walkers. Indeed, in their review of the disturbance impacts of dogs, Taylor *et al.* (2005, p. 56) conclude that 'There is *very little relevant research* that has focused on the effects of dogs *on animal groups other than birds*' (emphasis added). The central concern is that disturbance can cause birds, and other animals, to flee from cover or nests – impacting on their energy balances, feeding behaviour and the vulnerability of young, eggs or fledglings (Dahlgren and Korschgen, 1992; Fox and Madsen, 1997; Rasmussen and Simpson, 2010). Each of these potentially affects not only individuals but also populations through affecting breeding success, and can thus be a particular concern for endangered or vulnerable species of conservation interest.

Considerable attention has been given to flight responses of waterbirds (see for example Carney and Sydeman, 1999; Nisbet, 2000), but much less to forest bird species. Searches relating to the recreational disturbance of 35 'woodland bird' species found in the UK (as defined by Amar *et al.*, 2006) identified very few studies (Ibanez-Alamo and Soler, 2010; Lukac and Hrsak, 2005; Fernandez-Juricic, 2000a, 2000b; Fernandez-Juricic and Telleria, 2000; Fernandez-Juricic, Jimenez and Lucas, 2001, 2002; Mueller *et al.*, 2006). None of these studies were conducted in the UK and their findings are of limited relevance to UK woods in general. Five relate to empirical work in urban woodlands in Madrid, Spain, and conclusions from these studies are useful. Human disturbance was found to negatively influence the number of bird species, their persistence and guild density (Fernandez-Juricic, 2000b), along with blackbird feeding strategies, habitat selection and abundance (Fernandez-Juricic and Telleria, 2000). However, various factors affect animal's tolerance of disturbance and subsequent likelihood of flight, particularly the surrounding habitat structure and composition (Fernandez-Juricic, Jimenez and Lucas, 2001, 2002). In essence, alert distances and individual 'buffer zones'[†] vary with the presence of 'escape cover' such as shrub and tree cover. This effect is reported in the wider literature (e.g. Langston *et al.*, 2007). Interestingly, Fernandez-Juricic, Jimenez and Lucas (2002) noted that blackbird buffer distances were greater in 'highly visited' parks, which the authors related to habituation.

Studies relating to other birds associated with woodlands in the UK include black grouse (*Tetrao tetrix*) and capercaillie (*Tetrao urogallus*) (Figure 5). Baines and Richardson (2007, p. 56), for example, report that 'The disturbance regimes imposed had no discernible impact upon black grouse population dynamics' (although one study revealed a considerable impact of skiing on black grouse populations in the European Alps (Patthey *et al.*, 2008). An earlier study of red grouse (Picozzi, 1971) similarly showed no negative breeding impact, stating 'Grouse bred no worse on study areas on moors where people had unrestricted access, and Grouse bags showed no evidence of a decline associated with public access agreements' (p. 211). Newton, Robinson and Yalden (1981) investigated the potential impacts of recreational walkers on merlin (*Falco columbarius*) in the Peak District National Park. Their conclusion was that it was 'unlikely' to have caused the 'sharp decline in merlins during the 1950s' (p. 232), but that it could possibly slow recolonistation. Other studies of merlin (e.g. Meek, 1988) similarly suggest little negative impact by recreation, instead focusing on general habitat degradation by agriculture and pollution as the most likely causes of decline. In contrast, studies of capercaillie suggest a negative impact

**Figure 5** Capercaillie are sensitive to recreational activities.

[†] Defined in Fernandez-Juricic, Jimenez and Lucas (2002) as 'the difference between the distance at which a predator is detected and the distance at which the prey flees'.

by recreational activity (Summers *et al.*, 2004; Summers, McFarlane and Pearce-Higgins, 2007; Theil *et al.*, 2011). Summers *et al.* (2004) and Summers, McFarlane and Pearce-Higgins (2007) draw attention to the birds' avoidance of woodland areas near tracks and suggest a causal connection between this and recreational use. Although counts of recreational visitors in this study are very low, the authors find a statistically significant difference between capercaillie use of wooded areas adjacent to tracks classified as 'high' and 'low' human use. Extrapolation from total track length led these authors to assert reduced woodland 'carrying capacity' as the species avoids using between 21 and 41% of the two forests studied.

Studies of forest bird disturbance by walkers and dogs beyond the UK reveal some useful findings. In their study of 90 peri-urban (urban fringe) woodlands north of Sydney, Banks and Bryant (2007) identified a substantial, although seemingly short-term, effect of dogs on native birds – especially ground-nesters. They state 'Dog walking caused a 41% reduction in the numbers of bird individuals detected and a 35% reduction in species richness compared with untreated controls', but 'no net difference in bird diversity or abundance between areas with and without regular dog walking receiving the same treatment, suggesting that long-term impacts in this area may be small. (p. 612). In contrast, Gutzwiller *et al.* (1998, p. 497) 'found little evidence that intrusion altered vertical distributions of four passerines that nest, forage, sing, and seek refuge in subalpine forest. The minimal effects we observed indicate that the species we studied were able to tolerate low levels of intrusion.'. Similarly, in their study of nesting northern cardinals in riparian forests in Ohio, USA, Smith-Castro and Rodewald (2010, p. 130) 'found no association between nest survival and the tendency of birds to flush'.

On balance, the available evidence does not indicate significant negative impacts on UK forest birds following 'flight' responses to walking – including no clear long-term or population-level impacts.

A very few studies have attempted to assess the impacts of flight responses to walking on forest species other than birds. Some studies show, for example, that human presence on foot can in some circumstances disturb wild deer. Langbein and Putnam (1992) and Recarte, Vincent and Henison (1998) studied disturbance of British park deer, although came to different conclusions. Langbein and Putman (1992) reported significant immediate behavioural responses of deer to human presence, but these had no long-term impacts (such as on body-weights or overwinter mortality). Recarte, Vincent and Henison (1998) reported less disturbance and concluded that level of disturbance response was related to surrounding habitat and habituation. Other UK deer research includes Ward, White and Critchley (2004), who found that wild roe deer (*Capreolus capreolus)* (Figure 6) did not flee from, or otherwise change their behaviour, when disturbed by night-time ecological survey. They were found, however, to avoid paths and roads even at night when human activity was very low. In a US study, Miller, Knight and Miller (2001, p. 144) reported that 'For all species, area of influence, flush distance, distance moved, and alert distance (for mule deer) was greater when activities occurred off-trail versus on-trail' and that 'For mule deer, presence of a dog resulted in a greater area of influence, alert and flush distance, and distance moved than when a pedestrian was alone'. Studies by de Boer *et al.* (2004) and Marini *et al.* (2008) highlight a number of factors affecting the flight responses of wild deer. The structure of surrounding habitat is repeatedly identified as a major factor. In the only study of disturbance of squirrels by recreation identified in this review, Gutzwiller and Riffell conclude that 'Abundance of red squirrels at intruded [on foot] sites [in the US] did not differ significantly from that at control sites during either experiment.' (2008, p. 374).

Although immediate/short-term behaviour change may be apparent, this limited available evidence shows little or no long-term negative impacts upon UK forest mammals following 'flight' caused by walking in woodlands.

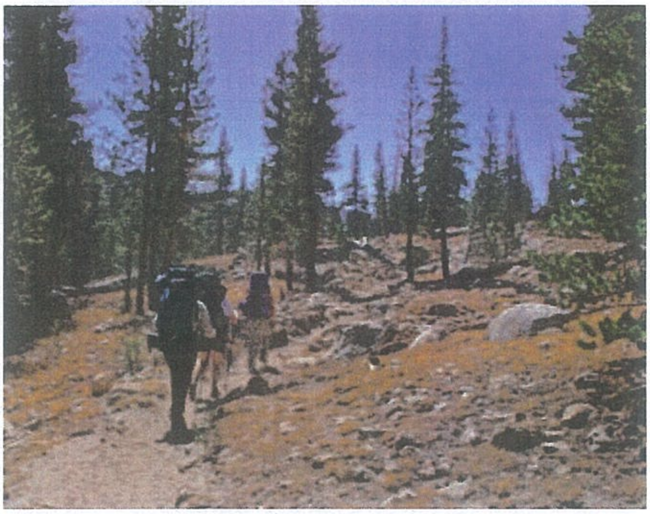
**Figure 6** Roe deer maintain their behaviour when disturbed.

## Introduction or spread of harmful species or pathogens

There is a small amount of evidence relating to the spread of harmful pests through walking and hiking activities in forests, although none in the UK (see also the sections on horse riding (p.14) and vehicles (p.15). In their study of hiking trails in California (Figure 7), Cushman and Meentemeyer (2008) found strong associations between human recreational trail use and the spread of *Phytophthora ramorum*. They state;

'At the local scale, we found that there was greater incidence of the pathogen in soil on hiking trails than in adjacent areas off trail. At the landscape scale, our data indicate that forests on public land open to recreation experienced greater disease severity than forests on private land closed to the public.' (p. 771)

**Figure 7** Hiking can increase the spread of disease.



Jules *et al.* (2002) also identify human footfall as a vector for disease spread, although they identify vehicular spread as much more significant. Turton (2005) identifies the spread of weeds and soil pathogens by walkers and vehicles along forest paths as a key environmental impact in the tropical forests of Queensland, and recommends the 'removal of mud and soils from vehicle tyres and hiking boots before entering pathogen-free catchments' (p. 140) as a management strategy.

## Cycling and mountain biking

The review of literature on environmental impacts of cycling and mountain biking include studies from the USA, Canada, Switzerland, UK and New Zealand. There is overall agreement in the literature that mountain biking in forests and wildlands has expanded rapidly (Ruff and Mellors, 1993; Symmonds, Hammitt and Quisenberry, 2000; Lathrop, 2003; Heer, Rusterholz and Baur, 2003; White *et al.*, 2006) (Figure 8). In urban forests, mountain biking is reported to have exceeded walking/hiking as the main recreational activity while higher mobility has increased the area of forest under intense use (Heer, Rusterholz and Baur, 2003). As Symmonds, Hammitt and Quisenberry point out, 'In general, bikers are committed and/or have a significant amount of time available for recreation' (2000, p. 552).

Impacts from mountain biking can be classified broadly into two categories: (i) habitat change (trampling and erosion); and (ii) flight and behaviour change (Lathrop, 2003). Some literature also suggests that cycling can cause wildlife mortality.

**Figure 8** Mountain biking is an increasingly popular activity.

### Habitat change

Many studies focus on the erosion and trampling impacts upon soils and vegetation of cycling and mountain biking. These include, for example:

- Leaving muddy ruts in and around trails (Jacoby, 1990; Geraghty, 2000; White *et al.*, 2006).
- Trampling of vegetation, uprooting plants and erosion by spinning wheels (Jacoby, 1990; Symmonds, Hammitt and Quisenberry, 2000; Thurston and Reader, 2001; Lathrop, 2003).
- Off-trail erosion and creation of impromptu paths (Cessford, 1995; Thurston and Reader, 2001). Water and mud can cause users to leave the trail (Jacoby, 1990; Littlemore and Barlow, 2005), although it is suggested that mountain bikers are generally less likely to leave trails relative to other users (Lathrop, 2003).

- Compacted soil, causing vegetation loss and erosion (Jacoby, 1990; Symmonds, Hammitt and Quisenberry, 2000; Thurston and Reader, 2001; McEvoy *et al.*, 2008).

- Trail width and incision impact increases in relation to trail slope (Wilson and Seney, 1994, White *et al.*, 2006) (Fgure 9).

**Figure 9** Mountain biking can cause trail widening and vegetation loss.

## Flight and behaviour change

While mountain biking literature focuses mainly on erosion and trampling of vegetation, some studies consider the behavioural impacts of mountain biking on species such as bison (*Bison bison*), pronghorn antelope (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*) (Taylor and Knight, 2003), North American elk (*Cervus elaphus*) (Naylor, Wisdom and Anthony, 2009), and mule deer, bobcat (*Lynx rufus*) and coyote (*Canis latrans*) (George and Crooks, 2006). These studies are generally comparative, and show that mountain biking does disturb wildlife, in that it causes individuals to use habitat differently. They do not identify any long-term negative impacts associated with this, however.

Mountain biking can also impact on wildlife in other ways. For example:

- Mountain bikers travelling at high speed (Figure 10) and probably not talking (making noise) are less predictable for wildlife and a potential safety hazard for other humans (Cessford, 1995; Taylor and Knight, 2003; George and Crooks, 2006).

- There can be direct mortality of wildlife through impact at high speed (Lathrop, 2003). Lathrop did not find many studies but highlighted anecdotal evidence suggesting that small mammals are particularly affected.

- Disturbance can cause and increase flight response. For example, Naylor, Wisdom and Anthony (2009) found that mountain bike disturbance increased the travel time of elk, which reduced time for feeding or resting.

Some literature reports little or no impact on wildlife by mountain bikers. For example, Lathrop (2003) cites research by Stake (2000) who was studying the golden cheeked warbler (*Dendroica chrysoparia*) at Fort Hood, Texas, before the introduction of mountain biking to the area. This study reported no impacts from mountain biking on territory density, return rates or age structure of the bird population.

**Figure 10** High speed riding is a danger to wildlife and humans.

## Horse riding

According to Newsome *et al.* (2002) horse riding usually occurs on specifically designed bridleways. The studies investigating the impacts of horse-riding on flora and fauna have been concentrated in Australia and the USA, particularly in national parks where horse-riding holidays or treks are common. Nevertheless, horse riding is an increasingly popular forest recreational activity in many countries (Landsberg *et al.*, 2001; Newsome,Cole and Marion, 2004) including the UK.

The key impacts of horse riding are related to: (i) habitat change; and (ii) spread of invasive weeds.

## Habitat change

Horse riding can affect wildlife habitat in a number of ways, including soil compaction, erosion, vegetation damage, increased trail depth and width, and sediment movement (Figure 11). Trampling can compact the soil and damage surface litter, lichens and mosses (Newsome *et al.*, 2002) and reduce populations of invertebrates (Littlemore and Barlow, 2005). Littlemore and Barlow state that 'In British woodlands, heavy trampling can severely reduce the population densities of soil and litter dwelling invertebrates by up to 89% in path centres and by 57% at path margins when compared to undisturbed soil profiles' (2005, p. 277–278). Landsberg, Logan and Shorthouse (2001) cite their own (Canberra Nature Park, Australia) and other studies (Summer, 1980, 1986) where they identify the terrain most vulnerable to trampling to include colluvial slopes, moraine sideslopes, wet bogs and alpine areas. Moreover, damage to trails is compounded by the use of shortcuts instead of following trails with switchbacks, or veering off the trail to avoid obstructions such as fallen trees (Landsberg, Logan and Shorthouse, 2001). Removal of vegetation can be greater when horses are going downhill (Weaver and Dale, 1978) but the level of damage is dependent on other factors such as soil type, climate, sensitivity of vegetation and management measures currently in place (Newsome, Cole and Marion, 2004).

**Figure 11** Horses can cause damage to soil and vegetation.

## Introduction or spread of harmful species or pathogens

As well as trampling, the potential for horses to spread invasive or non-native plants or pathogens is a concern (Gower, 2008) (Figure 12). Key aspects include the transportation of seeds or pathogens either through endozoochory (transporting seeds in the digestive tract) or epizoochory (via the horse's coat, hair or hooves) (Landsberg, Logan and Shorthouse, 2001; Gower, 2008; Pickering and Mount, 2010), and disturbance of soil providing suitable environments for the establishment of invasive species (Newsome *et al.*, 2002). Newsome *et al.* (2002) note that in protected areas in Australia invasion of the root-rotting fungus *Phytophthora cinnamomi* is a widespread problem. *Phytophthora cinnamomi* causes dieback in various tree species and can be spread through soil movement as horses move along trails (although vehicles and bicycle tyres and walkers' boots can also carry the fungus). The authors note that public appreciation of the impact of established non-native invasive species is often influenced by the fact that changes to the environment may only be discernible over a long period of time. Having said this, the limited evidence suggests that in general, horse riding in natural areas such as forests is not a substantial cause of biological invasion.

**Figure 12** The risk of horses spreading non-native plants along forest trails is minimal.

Gower (2008) believes that horses are not a significant vector for invasive species as germination success on forest trails is very low. Campbell and Gibson (2001, p. 23) conclude that 'the emigration of exotic species via horse dung does not pose an immediate threat to the plant communities adjacent to trails in these forest systems'. Torn *et al.* (2009, p. 235) note, similarly, that 'alien species may be introduced to natural forests through recreational horse riding', but that 'In practice, the risk of [these] alien species to the biodiversity of natural forests may be relatively small'.

## Vehicles

The main studies cited here are based on reviews of vehicle impacts from USA, Australia and France. Here, we have focused primarily on motorcycles and off-road vehicles, which have been variously termed all-terrain vehicles (ATV), off-road vehicles (ORV) and off-highway vehicles (OHV). The types of vehicles include 4-wheel drive, snowmobiles, large tundra buggies and trail bikes (Figure 13). Buckley (2004) suggests that OHV refers to vehicles used on recognised dirt roads and tracks which are not legal highways. The most commonly used term in the literature cited is OHV. In the USA, data from 1982 to 2001 showed that off-road driving was one of the fastest growing activities and almost 10% of all visits to national forests in 2004 involved OHV use (Zielinski, Slauson and Bowles, 2008 and references therein). However, there are few studies on the impacts of OHVs in forest settings (Buckley, 2004) and only one study based in the UK was found which included this as part of its analysis (Summers, 2007).

**Figure 13** Trail biking and other vehicle related activities can cause serious disturbance.

Buckley (2004) provides a useful review on impacts including compaction, erosion and trampling of soil, vegetation and fauna, transportation of weeds, and impacts on other wildlife through collisions and noise. He divides OHV impacts between plants/vegetation and vertebrates/invertebrates. Although some vegetation types are more resilient than others, generally disturbance from OHVs includes crushing and bruising of individual plants, modification of soil properties and introduction of weed seeds or pathogens. There are also risks for species in terms of habitat loss, greater energy consumption when reacting to disturbance and increased predation (Buckley, 2004).

### Habitat change

Physiological damage to plants can lead to reduced growth rates and premature leaf loss (Hylgaard and Liddle, 1994 in Buckley, 2004). Bunnell, Flinders and Wolfe (2006) highlight that snowmobiles can compact snow providing greater access to predators normally restricted by deep snow (see also Zielinski *et al.*, 2008).

### Introduction or spread of harmful species or pathogens

Whilst motor vehicles in general have been shown to be a significant vector for the spread of plants (Schmidt, 1989; Von der Lippe and Kowarik, 2007), including during tourist activities (Lonsdale and Lane, 1994; Pickering and Mount, 2010) and in forests (Veldman and Putz, 2010), only one study was identified directly investigating the dispersal of harmful species by recreational vehicles in forests and this reported only limited dispersal (Rooney, 2005).

### Flight and behaviour change

OHVs can crush animals and invertebrates, nests and burrows and collide with or run over and kill wildlife (Buckley, 2004; Burger *et al.*, 2007). Vehicle noise and speed can disturb a range of species such as songbirds, leading to displacement into potentially less favourable areas (Buckley, 2004; Blanc *et al.*, 2006). Research has also shown that wildlife will avoid areas where there are tracks and presence of human-related noise such as from OHVs. For example, Buckley (2004, p.88 and references therein) cites studies where species such as bears, wolves, elk, deer and lizards have decreased in density. A study on great bustards in central Spain (near Madrid) found that vehicle traffic was the most common source of disturbance inducing an escape response, which not only requires increased energy but also heightened the danger of collision with powerlines, the main cause of non-natural mortality of the birds (Sastre *et al.*, 2009).

Major one-off forest events such as car rallies (Figure 14) can lead to nest abandonment, particularly in birds of prey (RSPB, 1997 in Littlemore and Barlow, 2005). Tracks left by OHVs can fragment habitat and block movement of some species of small mammals, amphibian and invertebrates (Burnett, 1992; Goosem, 1997, 2000; Forman and Alexander, 1998 from Buckley, 2004).

Figure 14 Car rallies are a source of disturbance to birds.

## Camping and outdoor activities

The majority of papers reviewed here focus on camping with studies primarily from the UK and USA. Camping-related impacts can occur in areas where camping activities are intensive, including expansion of campsite areas and increasing number of sites (Leung and Marion, 2004) (Figure 15). However, some authors maintain that in fragile communities relatively low levels of use can cause significant impact (Leung and Marion, 2000 in Cole and Monz, 2003).

The main forms of impact include habitat change and flight and behaviour change (Cole and Monz, 2003; Leung and Marion, 2004; Littlemore and Barlow, 2005).

Figure 15 Intensive camping can cause habitat change.

### Habitat change

Studies highlight the impacts of camping in terms of tree damage, damage and loss of vegetation through trampling, and compacted soil and erosion. Further impacts include littering, vandalism and accidental fires (Johnson and Clark, 2000), along with the removal of wood material for firewood (affecting invertebrate habitat and nutrient storage/cycling), and changes in the organic structure of soils around fires (Figure 16).

Figure 16 Camp fires can change habitats and soil structure.

Johnson and Clark (2000) discuss the impacts of camping in the New Forest, UK, where wild camping in the first half of the 20th century resulted in considerable environmental damage leading to regulations where camping was restricted to specified sites. The New Forest contains significant areas of semi-natural woodland. Despite the reduction in campsites and pitches, disturbance from campers have been documented. The authors cite a case study 'Hollands Wood' where damages to the environment over a 28-year period were recorded including: (1) 84% of the mature trees lost, reducing canopy cover by 50%; (2) 76% of the site classified as heavily disturbed ground; (3) 16% covered by roads, tracks and buildings; (4) significant reduction in the variety and distribution of lichen flora (Cox and Rose, 1996 in Johnson and Clark, 2000, p. 98).

A study by Cole and Monz (2003) on the effect of camping on previously undisturbed sites in Wyoming, USA found that in coniferous forests with an understorey dominated by a (fragile) shrub *Vaccinium scoparium* (a species of huckleberry), even one night of camping could significantly affect vegetation cover and height.

However, Leung and Marion (2004) suggest that camping-related impacts are often less than other types of human-related disturbances. Indeed, some studies note largely neutral or no effects on wildlife from camping. Blakesley and Reese (1988, cited in Liddle, 1997) found that the presence of seven bird species was negatively correlated with campgrounds while seven were positively correlated. Cole and Monz (2003, p. 693) emphasise that the intensity and magnitude of impact depend on four factors:

1. Amount and/or frequency of use.
2. Season and/or time of use.
3. Type of user and their behaviour.
4. Durability of the campsite.

The impact of disturbance naturally depends on tolerance levels of wildlife, particularly plant communities.

### Flight and behaviour change

Swensen (1979 in Littlemore and Barlow, 2005) found that proximity to camping grounds lowered breeding success of ospreys. Moreover, impacts on wildlife can occur when birds and other species are attracted to food sources left by people in and around grounds (Liddle, 1997). Marion, Dvorak and Manning (2008) note wildlife that is attracted to human food can suffer nutritionally and is more vulnerable to predators and vehicle collisions.

## Watching nature

Wildlife watching – sometimes described as non-consumptive use of wildlife, wildlife tourism or as part of ecotourism – is increasingly popular (Figure 17) and can raise considerable revenue. Between 1989 and 1995 the 'ecotourism' industry grew worldwide from US $60 billion to $175 billion (Karp and Guevara, 2011) and is continuing to expand. Rodger, Moore and Newsome (2010) report that between 20 and 40% of international tourism involves some form of wildlife viewing. People expect to see wildlife (Lemelin and Wiersma, 2007). While participants in wildlife watching will have different interests and preferences (Vaske, Hardesty and Sikorowski, 2003), wildlife watching experiences can include unguided encounters in natural areas, specialised wildlife tours, managed local wildlife attractions and research, and conservation or education

**Figure 17** Red kite viewing is increasingly popular.

tours (Valentine and Birtles, 2004). However, as wildlife watching has increased so have concerns around disturbance to wildlife populations and habitats (Higginbottom, 2004; Rodger, Moore and Newsome, 2010).

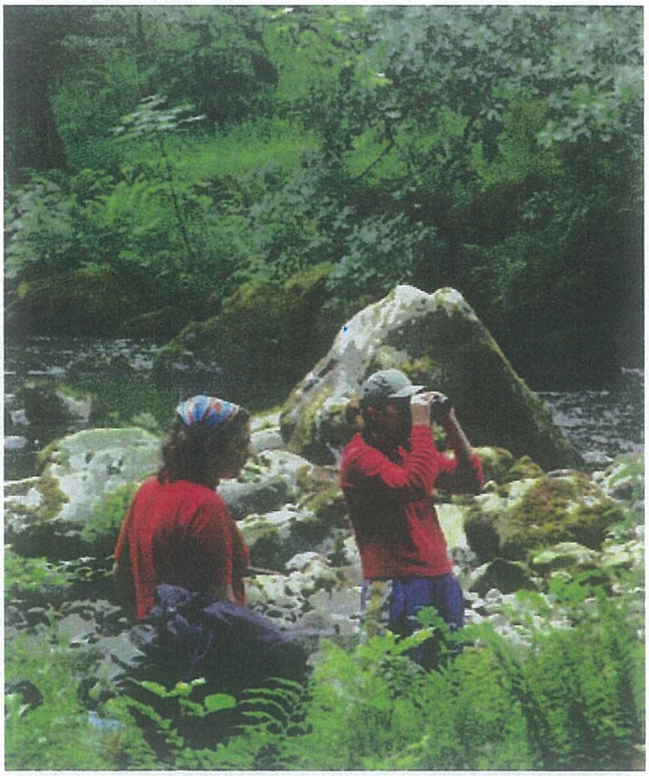
## Flight and Behaviour change

Most reported disturbance issues around watching wildlife relate to flight and behaviour change – particularly impacts associated with approaching animals for viewing, touching, feeding and photographing (Valentine and Birtles, 2004; Green and Giese, 2004; Lemelin and Wiersma, 2007). For example, Wolf and Croft's (2010) study of tourists and kangaroos in Australia suggests that talking within the group or conversation directed towards the animal contributed to the impact of their approach on wildlife. Karp and Guevara (2011) discuss the impacts of increasing ecotourism activities on rainforest birds in Peru, particularly conversational noise, which can provoke 'predator responses' such as fleeing, increased vigilance, vocalisation cessation and moving to new territories. Although reactions to human and mechanical noise can vary among species, the authors reported a decline in abundance of forest birds in relation to average conversational noise of 50 dB. Insectivore bird species were the most affected. However, they did note that a predator response may be due to the fact that many of these species are hunted by humans in this part of the world. Further examples include human presence interfering with foraging behaviour of mammals and birds (e.g. bald eagles, ravens and woodpeckers (Figure 18)) such that they avoid preferred foraging sites with a consequent reduction in quality or quantity of food (Green and Giese, 2004). Food-conditioned wildlife can abandon territories and move to more exposed recreational sites (Marion, Dvorak and Manning, 2008). Small mammal populations can reach unnaturally high levels leading to disease transmission or starvation during the off-peak season when people (and the food they carry) are scarce (Marion, Dvorak and Manning, 2008). There is also a risk that wildlife can become aggressive towards humans.

**Figure 18** Human activity can disturb birds such as the great spotted woodpecker.

Birdwatching is a hugely popular recreational activity in many countries and a good example of nature watching with 46 million birdwatchers reported in the USA, although only a fraction will be 'committed birdwatchers' (Sekercioğlu, 2002; Valentine and Birtles, 2004) (Figure 19). Numbers of birdwatchers in the UK vary between 10 000 and 1 million depending on how you define birdwatching (e.g. based on skills, participation in surveys). Birds are particularly popular as they are easy to see and identify but for many people birdwatching is a form of serious leisure (Stebbins, 1992; Leip, 2001; Bell, Marzano and Podied, 2010), a term that refers to leisure activities that require practitioners to invest considerable time, effort and often financial resources to attain expert knowledge and skill. The act of birdwatching can have positive or negative impacts on birds. As Sekercioğlu (2002, p. 282) has pointed out, birdwatchers represent an 'environmentally conscious segment of ecotourism' (see also Bell, Marzano and Podied, 2010). However, there are incidences where recording or photographing birds can have harmful effects, particularly in competitive birdwatching with the importance of birding 'lists' (e.g. local patch list, county list, UK list) and 'twitching' (e.g. those who travel at short notice to see a rare bird). These can impact on rare and vulnerable

**Figure 19** Bird watching can have positive and negative impacts.



bird species and potentially the habitat in which the bird species is found (e.g. through destruction and trampling). Intrusive photography, playing bird call tapes, flushing and approaching birds, particularly during the breeding season can lead to nest abandonment and egg loss due to nest predators (Sekercioğlu, 2002).

## Other activities

Other activities cited in the literature include orienteering, skiing, picnicking (Figure 20) and paintballing. Orienteering events can lead to trampling of flora and creation of new paths, erosion and disturbance of fauna if not properly managed (Anderson and Radford, 1992; Littlemore and Barlow, 2005; McEvoy *et al.*, 2008) (Figure 21). Research by Watson and Moss (2004) in Scotland on the impacts of recreation on ptarmigan found that crows attracted by the development contributed to a reduction in breeding success up to 4 km from a car park. Ski wires also led to ptarmigan deaths. A study by Patthey *et al.* (2008) on black grouse populations in the north-western European Alps highlighted the following potential impacts of disturbance from ski lifts and outdoor winter activities: habitat destruction and modification of native vegetation reducing faunal species richness, increased stress response from free-riding winter sports such as ski mountaineering, and mortality from collision with cables (see also the Walking and hiking section on p.9). The authors found that black grouse abundance was 36% lower in ski resort sites than in natural areas. Very little research has investigated the impacts of picnicking. Liddle (1997) refers to just two studies both conducted in the 1970s. These indicate that soil erosion and compaction can be significant, and affect soil moisture content in particular. However, Leney 1974 (cited in Liddle, 1997) revealed that some species (beetles and craneflies) were in fact promoted at the majority of the picnic sites in her study. Paintballing in UK woodlands became hugely popular in the late 1980s and 1990s and, although perhaps it is not as widespread as it once was, impacts include soil compaction, erosion, trampling of ground flora and base of trees, damage to regenerating trees, and disturbance of small mammals, ground-nesting birds and soil invertebrates (Hatton, 1991; Littlemore and Barlow, 2005).

**Figure 20** Picnicking beside Llyn Llewelyn, Beddgelert forest.

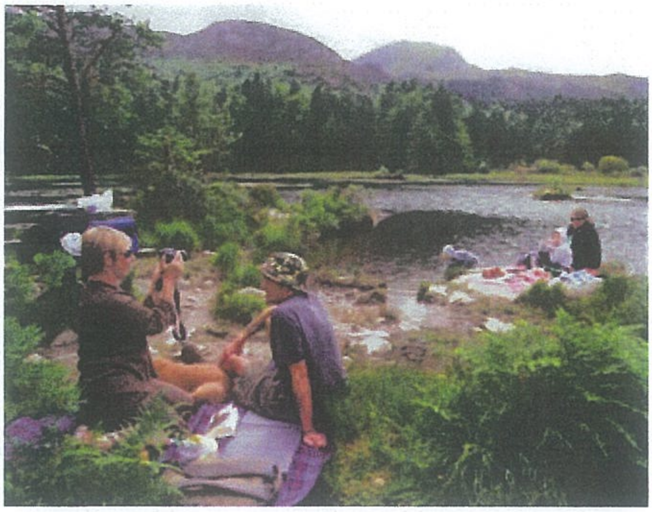


**Figure 21** Orienteering needs to be properly managed to avoid disturbance to flora and fauna.

## Longevity of impacts

Understanding the longevity of impacts from recreational use on forests is critical to designing management plans. If vegetation damaged by trampling recovers quickly, forest managers may be able to address problems through short-term measures. However, long-lasting impacts are likely to require more strategic approaches. As a general rule it is clear that while impacts can and do occur rapidly, recovery is relatively much slower (Cole, 2004). However, this does not mean that recovery is slow *per se*, and many recreation ecology studies report limited long-term impacts, if any. In a study in Belgium, Roovers *et al.* (2004) show that forest vegetation recovery 'during the first year after trampling was limited in most plant communities' but that rates differed across forest community type. Kissling *et al.* (2009, p. 303) compared short- and long-term studies of impacts across a number of vegetation and soil indicators, and concluded that 'it could be problematic to use the results of short-term trampling experiments to predict general long-term trampling effects'. Smith-Castro and Rodewald (2010) state that 'our findings suggest that the responses of birds to human use of recreational trails have only short-term effects, with no apparent effects of on nest survival'. Banks and Bryant (2007) also reported largely short-term, rather than long-term, effects of dogs on ground-nesting birds, and Thurston and Reader (2001) report quick recovery of plant stem density and species richness following high levels of impact on trails.

## Comparing disturbance impacts of different recreational uses

A number of the articles reviewed provide some comparisons between impacts of various recreational uses, the most common being walking/hiking, cycling/mountain biking, horse riding and off-road vehicles (including motorcycles). Much of the comparative material is contextual, based on specific case studies and dependent on factors such as the recreational activities most common in the study area as well as the species and habitat being studied (Table 4).

In an early comparative study by Weaver and Dale (1978, p.451) on trampling effects in the Rocky Mountains, the authors found that horses and motorcycles were more damaging than hikers. However, the authors also established that motorcycles created more damage to soil and vegetation when going uphill while hikers and horses were most damaging when going downhill. On level ground, horses were most destructive and hikers least destructive (Weaver and Dale, 1978, p.453).

Torn *et al.* (2009) compared the impacts of hiking, skiing and horse riding on forest trails and vegetation, noting that 'Horse trails were as deep as hiking trails, even though the annual number of users was 150-fold higher on the hiking trails' (p.1427). Thurston and Reader's (2001) study in a mature Canadian deciduous forest found little difference between impacts of mountain bikers and hikers on vegetation. Plant stem density and species richness were reduced by nearly 100% during experiments with highest intensity but can recover quickly once either use is halted (see also the Longevity of impacts section on p.20). Greatest damage occurred in the centre zone of the trail. Ruff and Mellors (1993) also maintain that there was no solid evidence suggesting that mountain biking is any more damaging to bridleways than walking or horse riding although they do acknowledge it can contribute to overuse of countryside sites.

Thurston and Reader (2001) conducted an experiment comparing the impact of mountain bikers (and hikers) on soil and vegetation. The study site in Canada was located in a mature deciduous forest with the predominant soil type being well-drained fine sandy loam. No timber harvesting was taking place. The number of passes over a particular area ranged from 1 to 500. The authors cite Cole and Bayfield (1993) who suggest that 500 passes was

**Table 4** Details of selected comparative studies.

| Study | | Activities compared | | | | Comparison |
|---|---|---|---|---|---|---|
| First author | Date | Walking | Cycling | Horse | Off-road vehicle use | |
| Trampling studies | | | | | | |
| Buckley | 2004 | ✓ | | | ✓ | Vehicles significantly greater impact |
| Littlemore | 2005 | ✓ | | | ✓ | Vehicles significantly greater impact |
| Ruff | 1993 | ✓ | ✓ | ✓ | | No difference |
| Thurston | 2001 | ✓ | ✓ | | | No difference |
| Torn | 2009 | ✓ | | ✓ | | No difference |
| Weaver | 1978 | ✓ | | ✓ | ✓ | Vehicles and horses slightly greater impact |
| Wildlife disturbance studies | | | | | | |
| Blanc | 2006 | ✓ | | | ✓ | Walking significantly greater impact |
| George | 2006 | ✓ | ✓ | ✓ | ✓ | Walking and biking no difference but greater impact than other activities |
| Lathrop | 2003 | ✓ | ✓ | | | Biking significantly greater impact |
| Naylor | 2009 | ✓ | ✓ | ✓ | ✓ | Vehicles significantly greater impact than all other activities |
| Sastre | 2009 | ✓ | | | ✓ | Vehicles significantly greater impact |
| Wolf | 2010 | ✓ | | | ✓ | Walking significantly greater impact |

sufficient to cause a 50% reduction in vegetation cover for most vegetation types. The effects of mountain biking (and hiking) were first measured two weeks after the experiment and then after one year based on recommendations by Cole and Bayfield (1993) to identify damage and resilience of vegetation type. The study found that while vegetation loss increased with increasing pass activity, there was no significant difference between bikers and walkers in terms of pass intensity or vegetation loss.

In comparing the impact of different users one study found that there was no evidence that mountain biking should be managed any differently from hikers although it is noted that mountain bikers cover more ground (they are faster) so may disturb more wildlife per unit time (Taylor and Knight, 2003). A mountain biker travelling downhill at high speed might stress wildlife more than a hiker (Lathrop, 2003). Moreover, activities which are fast-moving but quiet such as mountain biking and jogging are less predictable for wildlife than slower activities such as hiking (Sterl, Brandenburg and Arnberger, 2008). Sterl, Brandenburg and Arnberger (2008) provide an example (from Gander and Ingold, 1997) of alpine chamois (*Rupicapra rupicapra*), which fled greater distances when encountering mountain bikers and joggers as opposed to hikers.

George and Crooks (2006) conducted a study of human recreational disturbance on coyotes, bobcat and mule deer within the Nature Reserve of Orange County, California. They found that the most common recreational activity in this area was hiking, followed by mountain biking, off-road driving and horse riding. Both bobcat and coyote activity was spatially displaced by human activity, particularly biking and hiking (but not driving or horse riding). However, in most instances walking and hiking are shown to have either similar (i.e. no worse) or less impact than other recreational activities. For example, Banks and Bryant (2007, p.612) stated that 'Humans walking alone also induced some disturbance but typically less than half that induced by dogs'.

In relation to disturbance of North American elk, Naylor, Wisdom and Anthony (2009) found that mountain biking and hiking did not negatively impact as much as all-terrain vehicles. The authors suggest that once elk had moved away from the routes in question they could resume foraging activity but that mountain biking did increase elk travel time and decrease feeding time. The authors also found that the highest travel response of elk in north-east Oregon was related to vehicle activity (compared to hiking, mountain biking and horse riding). Nevertheless, the authors note that peak feeding time is during dawn and dusk, which will rarely coincide with high traffic. A study on great bustards in central Spain (near Madrid) found that vehicle traffic was the most common source of disturbance (escape response) followed by walkers (a group that produced a higher alert response) and was higher at weekends and holidays when recreational activities are more pronounced (Sastre *et al.*, 2009).

The impact of off-highway vehicles (OHVs) depends on driving practices and habitat and species type (Buckley, 2004). There are some differences in the literature over the extent that OHVs can cause disturbance impacts. For example, OHVs have been said to cause up to 5 to 30 times more damage to vegetation than hikers (Buckley, 2004; Littlemore and Barlow, 2005). Intuitively, one might believe that OHVs would disturb wildlife far more than other non-motorised recreational use. However, Bayfield (1986 in Newsome, Moore and Dowling, 2001) showed that in the Cairngorms the ecological impacts of OHVs were limited but social perceptions relating to potential impacts of OHVs were far greater. In a study on the impacts of tourists and wildlife watching on wild kangaroos in Australia, the authors found that flush response was lower when vehicles approached than pedestrians (Wolf and Croft, 2010). They state, 'Our behavioural observations showed that the two kangaroo species treated an approach on foot with more alarm than a vehicle approach as the time spent in vigilance behaviour, hiding or aversion movements increased by 30%'. OHVs also did not affect spatial distribution and occurrence of martens in California, USA although the authors note that as martens are nocturnal, secretive creatures, it would have been too difficult to study the direct impact of OHV disturbance on behaviour (Zielinski, Slauson and Bowles, 2008). Similarly, Blanc *et al.* (2006) maintain that vulnerable bird species in France were disturbed more by walkers, with or without dogs, than by OHVs (56.8% as opposed to 2.4%).

## Recreational users' perspectives

Few studies exist on the extent to which different user groups perceive their own and others' impacts on the environment but Dorwart, Moore and Leung (2009) maintain there is a link between activities carried out, preferred places and visitor behaviour, attitudes and expectation. There are debates over whether participation in outdoor recreation increases pro-environmental attitudes and behaviour (Bright and Porter, 2001; Cordell *et al.*, 2002). However, Lemelin and Wiersma (2007) found in their study on impacts of tourism on polar bears that people can detach concerns about environmental issues from how they behave outdoors. Generally, it seems that user groups have little awareness of the impacts of their activities and hold other user groups responsible for negative impacts of recreation on wildlife (Geraghty, 2000; Symmonds, Hammitt and Quisenberry, 2000; Taylor and Knight, 2003; Manning *et al.*, 2004; Sterl, Brandenburg and Arnberger, 2008). Interestingly, a survey carried out by Taylor and Knight (2003) on recreational disturbance to three large mammals in a US case study found that 50% of the visitors surveyed did not believe that recreation has a negative impact on wildlife. Although unintentional and intentional feeding of wildlife has been reported as a problem in places where nature watching or other activities such as camping take place, Marion, Dvorak and Manning (2008) reported that only a minority of respondents in their study on chipmunks admitted to feeding wildlife. Other studies present similar findings where recreational users do not believe their activities affect wildlife even if they see animals respond to their actions and particularly if they are obeying prescribed rules and regulations (Thompson *et al.*, 1987; Cooper *et al.*, 1981 in Klein, 1993).

Sterl, Brandenburg and Arnberger's (2008) study which investigated visitors' awareness of recreational disturbance on wildlife in an Austrian urban national park found that dog walkers believed that off-trail users impacted more on wildlife and off-trail users had similar impressions of dog walkers. However, the authors suggest that the answers given by recreational user groups such as dog walkers were influenced by their concerns over the safety of their own animals. For example, this group stated that cyclists disturb wildlife but were actually concerned about cyclists impacting on dogs that are off leash. Nevertheless, this study is particularly interesting as it focuses on a small national park which is highly used due to its urban location, network of trails and unlimited access. The main users of the park are cyclists, walkers/hikers, dog walkers and joggers, while in winter skiing is a popular activity. The study took place in the winter as this is a problematic time for wildlife such as deer species because of the lack of tree and shrub cover. Visitors (*n*=271) were interviewed and divided between three groups: (1) dog walkers; (2) on-trail walkers; and (3) off-trail walkers. The study's objective was to find out which activities (out of a list of 14 presented) were perceived by visitors to potentially impact on wildlife in the park, whether visitors were aware of their own potential impact and if they felt other user groups had an impact on wildlife. General results showed that off-trail biking and dog walking are perceived to have the highest impacts on wildlife. Roe deer and birds were the species most mentioned, while disturbing activities were felt to be the result of high visitor numbers, noise or dogs. However, 60% of interviewees did not believe that recreational use disturbed wildlife and only 12% of visitors stated that they had disturbed wildlife during their visit. When asked why their presence had not disturbed wildlife, 75% of respondents believed it was because they had engaged in unobtrusive behaviour, stayed on the trails and were quiet. Another perception was that wildlife had not been disturbed if they had not been seen (see also Lemelin and Wiersma, 2007). Visitors judged certain activities such as walking and cross-country skiing to have low impact on wildlife. However, the authors did point out that off-trail users could cause greater disturbance than, for example, those who stay on trails as they tend to stay in the park for longer and disperse across wider areas. Moreover, while fewer people may take part in cross-country skiing, it is a relatively quiet and fast-moving activity, which can have significant impacts on wildlife, particularly off-trail.

Taylor and Knight (2003) compared mountain bikers' and hikers' perceptions of their effects on wildlife. Respondents were asked: (1) how close they felt it was acceptable for recreationists to approach wildlife (wildlife flight distance); (2) how far they thought animals moved if they fled from recreationists (distance moved); (3) to what degree they believed wildlife was being affected by recreation; and (4) which recreational users group they felt was most responsible for causing stress to wildlife. The findings highlighted that recreationists were having a greater effect on wildlife than they thought. A key difference was that most recreationists felt they could approach wildlife at a much closer distance than wildlife would allow according to the experimental trials that were also carried out.

The emergence of mountain biking as a popular form of recreation has had a particular effect on other users over the past two decades. Previously, negative perceptions surrounding mountain biking may have arisen because they were an unfamiliar presence in the landscape (Ruff and Mellors, 1993). Thus, some found mountain biking to be out of place in the countryside (Jacoby, 1990; Cessford, 1995), possibly because users are happy to encounter 'their own kind' but do not like faster or more mechanised users (Jacoby, 1990; Cessford, 1995). Others feel that the addition of mountain biking is damaging to existing trails (Thurston and Reader, 2001). Heer, Rusterholz and Baur (2003) cite studies from Moore (1994) and Hoger and Chavez (1998) who report that hikers believed mountain bikers negatively affected the environment such as through the creation of informal trails.

In Symmonds, Hammitt and Quisenberry's (2000) study, 700 mountain bikers were asked to rate their impact on trails compared to horse riders, walkers/hikers and motorised vehicles. They rated themselves as being less damaging than horse riders and vehicles but more damaging than walkers/

hikers. The authors note that perceptions are often different from actual behaviour with 42% perceiving that they had a medium level of impact on trails and 39% a low impact. Nevertheless, 91% of mountain bikers acknowledged that mountain biking caused some degree of trail erosion with the remaining 9% stating that it had no effect (Symmond, Hammitt and Quisenberry, 2000).

A mountain-biking study conducted in the UK (Geraghty, 2000) compared the perceptions of mountain bikers, hikers and horse riders of the impact these recreational groups have on the countryside. The three user groups were represented in the study and most of the 73 participants believed that the other recreational groups caused more damage to trails than their own recreational activity. For example, horse riders were aware that horses' hooves might cause trail damage but they believed that mountain biking 'behaviour' and the fact that mountain bikers tend to concentrate in one area would have a greater impact on the environment.

Heer, Rusterholz and Baur (2003) conducted a study of perception and knowledge of mountain bikers and hikers relating to forestry, nature conservation and social conflicts in the northern Jura Mountains, Switzerland. They found that neither the type of recreational activity nor any aspect of the forest visit (e.g. how frequently they visited the forest, how long they stayed in the forest, how far they travelled etc.) had any influence on knowledge and perceptions. However, the authors did point out knowledge did not necessarily result in a change of behaviour and some of the respondents were unaware of the impact of their activities.

Only Buckley (2004, p. 83) makes reference to vehicle user attitudes suggesting that, 'there are also many recreational users of OHVs, both private and commercial, who drive them with no concern for environmental impacts and in places of high conservation value'.

Newsome *et al.* (2002) cite a US survey of environmental managers by Shew *et al.* (1986) that had received public complaints about horses including: campsite damage, tethering damage, manure on trails and associated insects and trail damage. Aside from the usual conflicts between recreational uses there appears to be some opposition to horse riding on conservation grounds, particularly in Australia and the USA (although see Miller, Dickinson and Pearlman-Houghgie, 2001 in relation to UK National Parks). Newsome *et al.* (2002) believe that 'in many cases horse-riders are indifferent to or unaware of their effects on the environment (UK CEED, 2000; D. Newsome, personal observation)'.

Taylor and Knight (2003) surveyed 640 recreationalists (hikers, mountain bikers and horse riders) on Antelope Island in Utah and revealed widespread support for the use of penalties for recreationists who chased or intentionally stressed wildlife. However, they were less supportive of closing trails seasonally and establishing minimum approach distances to wildlife. There was little support for having fewer trails on the island, requiring visitors to watch an educational video on effects of recreation on wildlife or allowing only one type of recreational use (Taylor and Knight, 2003).

## Managing impacts

According to Marion, Dvorak and Manning (2008) management can be direct, such as leaving little room for individual freedom of choice, or indirect, where attempts are made simply to influence the decisions and behaviour of visitors. Higginbottom (2004, p. 218–221) in her edited volume on wildlife tourism provides two sets of management options or tools to manage recreational use. The first relates to management of wildlife tourism at sites including restriction of visitors to specific wildlife areas, dispersal of visitors to reduce impacts on wildlife and habitats at sites (although there are opposing views that suggest dispersal can cause more damage – see Cole, Petersen and Lucas, 1987), installing approach distances and temporal restrictions, and managing expectations in relation to what visitors expect to experience (e.g. handling or touching animals). The second relates to more strategic actions such as external regulations (by government), economic instruments, industry self-regulation, physical alterations to environment to withstand visitor pressure, cooperative agreements, education and marketing. Some evidence is available in relation to management of sites and is outlined below.

A range of management options have been identified in the literature relating to different recreational users. Management can involve setting aside new areas for recreation, physical and natural barriers, provision of track alterations, temporal restrictions, informational and/or warning signs, trail maintenance, habitat restoration, screening vegetation for wildlife, impact surveys, buffer zones or minimum approach distances. Various codes of conduct such as the Camping and Caravan Club Environmental Code (Johnson and Clark, 2000), UK Countryside Code and universal 'Leave No Trace' policy (Cole and Monz, 2003; Littlemore and Barlow, 2005) promote informed self-regulation.

Cole, Petersen and Lucas (1987) provide a broad view of management solutions aimed at tackling disturbance problems in natural 'wilderness' areas. Eight general 'strategies' are identified, which are then populated by more detailed 'tactics'. The strategies, some of which clearly demand social scientific knowledge, are:

1. Reduce use of the entire wilderness.
2. Reduce use of problem areas.
3. Modify the location of use within problem areas.
4. Modify the timing of use.
5. Modify type of use and visitor behaviour.
6. Modify visitor expectations.
7. Increase the resistance of the resource.
8. Maintain or rehabilitate the resource.

Tools for planning and managing recreational need with conservation requirements are available but are most easily identified in literature from the USA and Australia. There is one UK reference to Environmental Management Systems relating to integrated management that includes outdoor recreation (Font *et al.*, 2001). The most cited tools are the Recreational Opportunity Spectrum (ROS) (Clark and Stankey, 1979) and Limits of Acceptable Change (LAC) (Stankey *et al.*, 1985; McCool, 1996), but there are others such as Visitor Impact Management (Knight and Gutzwiller, 1995), Visitor Experience and Resource Protection (VERP) (National Park Service, 1997a, 1997b), Experience-based Management (Manfredo *et al.*, 2002) and Ecological Regional Framework (White *et al.*, 2006) (see Leung and Marion, 2004 for an overview). As Higginbottom (2004, p. 212) has pointed out, most of these tools or models share key elements that are central for effective management of recreational disturbance. They include: clearly defined management goals and objectives, indicators and standards to show where objectives have been achieved, management actions to meet the objectives, implementation of monitoring and evaluation programmes and a clearly documented process involving all of these elements. However, Higginbottom (2004, p. 219) notes the difficulties in determining the effectiveness of various management actions suggesting they are 'mostly complex and poorly understood'. Monitoring programmes are needed to records levels of use of each recreational activity, users' compliance with management constraints and impacts of recreational activities on wildlife. Below we briefly identify three broad sets of management options.

## Zoning, 'set-back' distances and exclusion

Knight and Temple (1995) identify three main categories of access restriction aimed at reducing wildlife disturbance by recreational activities: buffer zones, time restrictions and visual screens (Figure 22). Establishing 'buffer zones' is a common method, the range of which can be derived from flight response and distance research (e.g. 'alert

**Figure 22** Kielder Campsite screened by trees.

initiation distance'). These can be calculated according to area of influence (area or trail or line of human activity where wildlife is likely to be disturbed) or perpendicular distance, which is the shortest distance between humans carrying out an activity and wildlife (Taylor and Knight, 2003). Time restrictions include daily and seasonal access restrictions, while visual screening (e.g. through vegetation) can be effective in shielding wildlife from human activities, reducing the impact.

Management strategies have formed a large part of discussions in the camping literature, such as the use of 'dispersal' or 'containment' strategies to spread or contain the risk of camping impact (Leung and Marion, 2004; Kangas *et al.*, 2007). A definition is provided by US authors Leung and Marion (2004, p. 249–250):

'A campsite containment strategy seeks to reduce the total extent of impacts by concentrating camping use to a small number of campsites, which receive a higher frequency of use. Conceptually this approach can be applied to a temporal scale, with camping use being concentrated during specified seasons or times'.

There are still potential problems with site expansion and creation of 'social access trails' but these can be minimised by good spatial planning, which is informed by an understanding of campers' needs and activity patterns (Johnson and Clark, 2000; Leung and Marion, 2004).

Even at relatively low levels, inappropriate recreational activity can cause considerable damage, particularly to vulnerable habitats and species, and in the literature there are some doubts as to whether self-regulating systems would work, particularly in large nature reserves (Newsome *et al.*, 2002). As an example, prohibiting all horse riding opportunities is unlikely to be socially or politically acceptable, but in Australian national parks, Newsome *et al.* (2002) advise park authorities to restrict free access and authorise commercial operators to provide tours in designated areas through a permit basis, thereby enforcing low levels of use (see also Miller *et al.*, 2001). A monitoring programme of the commercial horse-riding operation is considered essential (Figure 23). Also in Australia, Landsberg, Logan and Shorthouse (2001) provide 10 principles to guide management of horse riding in peri-urban nature reserves including trail maintenance and exclusion zones.

Some authors (e.g. Newsome *et al.*, 2002) believe that restriction or rationing recreational use in vulnerable areas is a more effective management tool than 'education'.

**Figure 23** Horse rider entering the Wilverley enclosure, New Forest.

## Marketing

According to Moscardo and Saltzer (2004) marketing is often seen as negative due to its association with sales and commercial interests. However, one key aspect of studying tourism and recreational markets involves an understanding of who the 'customers' are, their needs, expectations and motivations, how they currently behave and ways in which this behaviour can be influenced to lesson negative impacts on wildlife. Social marketing is an approach that focuses on behaviour change for individual or societal gain (Kotler and Lee, 2008). It is essentially based on developing an understanding of what people do and providing a framework for behavioural interventions. In order to facilitate behaviour change, the interventions should be fun, easy and acceptable to a wide range of people (e.g. a social norm) (www.snh.org.uk) . A range of literature stresses the importance of understanding user perspectives and behaviour (Symmonds, Hammitt and Quisenberry, 2003; Taylor and Knight, 2003). In the UK, Littlemore and Barlow (2005) emphasise the role of stakeholder engagement in encouraging user groups to stick to specific areas or trails. They suggest contacting 'official organizations to help spread the word as a higher degree of user and owner compliance will be initiated by consultation, planning, interpretation and all understanding their roles and responsibilities' (p. 282). However, no studies have been identified which use marketing approaches to investigate recreational disturbance issues.

## Education and interpretation

Management proposals in a number of the papers we reviewed often involved a recommendation for visitor 'education' programmes as it is presumed that people are unaware or unwittingly disturbing wildlife (Cole, Hammond and McCool, 1997; Sterl, Brandenburg and Arnberger, 2008). There are suggestions that managers should investigate and consider visitor perceptions when planning any actions so that visitors are more likely to understand the benefits to wildlife and be accepting of measures (Taylor and Knight, 2003). For example, education initiatives can provide information on the impacts of recreation on wildlife such as increased stress levels (Heer, Rusterholz and Baur, 2003; Taylor and Knight, 2003). Marion and Reid (2007) write about the efficacy of low-impact education programmes in protected areas. They note that visitor information (Figure 24) and education programmes (Figure 25) which aim to 'persuade' visitors to adopt low-impact behaviour are a light-handed but effective management response to reduce impacts. The focus is on encouraging appropriate behaviour rather than trying to control visitors. 'Visitors retain their freedom of choice but information that considers the consequences of their actions guides their behaviour' (p. 6). The international 'Leave No Trace' programme, targeted primarily at campers but also other recreation users, is an example of awareness

**Figure 24** Getting information in the forest shop at Grizedale, Cumbria.

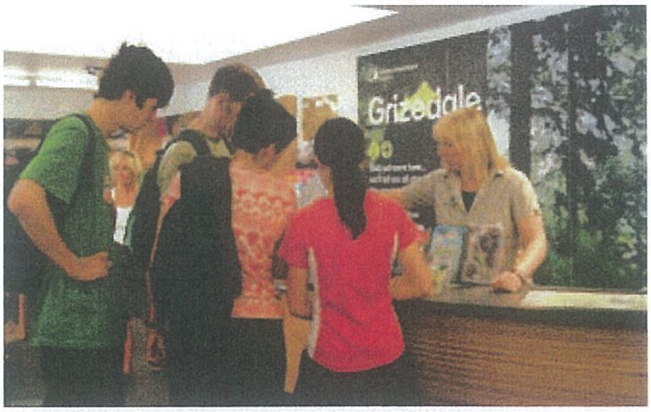



**Figure 25** A Forestry Commission education ranger conducting a networking day.

raising of the potential negative impact of visitor activities and providing information on the most appropriate practices to avoid or minimise impact (Marion and Reid, 2007, www.lnt.org/programs/principles.php).

Four conceptual approaches have been identified by Marion and Reid (2007, p. 10 and references therein) to understand how education may influence an individual's behaviour. The first looks at moral appeals made to visitors at different stages of moral development. The authors suggest that message delivery is important and messages which provide a rationale for recommended behaviour (i.e. why it is important) are more effective than simple statements on how to minimise impact.

However, there are limitations associated with any educational programme, not least of which is the pervasiveness of the 'knowledge deficit' concept (Durant, Evans and Thomas, 1989; Miller, 2001) where individuals are conceptualised as rational actors and certain (usually negative) behaviours are attributed to a simple lack of scientific information. Studies have illustrated the complexity of the relationship between 'lay' person behaviour and their knowledge, understanding and use of 'science' and other forms of information (e.g. Wynne, 1995). As Cynn *et al.* (2002 cited in Moscado and Saltzer, 2004, p. 176) point out 'the relationship between environmental awareness, intention and behaviour is tenuous, particularly in the context of tourism' (see also Lemelin and Wiersma, 2007). It is clear, therefore, that educational programmes focused on modifying recreationists' behaviour require careful design and considerable insight into the diversity of visitors and the ways in which recreationists' understand and use information.

'Interpretation' is closely related to 'education' (they are often considered together) and can take several forms, from signage through to on-site advice direct from guides or officials (Figure 26). These methods have been shown to work differently across varied situations and audiences/social groups. Hughes and Saunders (2005) suggest that visitors' response to on-site interpretation is linked to their intended activity and those taking part in exploratory activities such as hiking and wildlife watching were more likely to be interested in conservation messages. Littlefair and Buckley (2008) report that 'minimal-impact interpretation' significantly reduced the ecological impacts of visitors to an Australian National Park/World Heritage Site (see Marion and Reid, 2007 for a review of 'low impact' education and interpretation methods). Cole, Hammond and McCool (1997) cite the work of McGuire who produced a model to identify how interpretation 'messages' are processed. The model involves six steps:

**Figure 26** Visitors read the interpretation panel at Nash Carpark, Presteigne.

exposure (to the message), attention (reading the message), comprehension (understanding the message content), yielding (acceptance of the message), retention (stored in memory for later use) and behaviour (changes in accordance with message content). Cole, Hammond and McCool tested whether exposure to low-impact messages on trailside signs would increase visitors' knowledge of appropriate practices. Through various trials the authors posted between two and eight messages on a message board along with a topographical map. They noted if visitors (*n*=506), consisting of hikers (65%) or horse riders (35%) stopped to look at the messages on the bulletin board and how long they spent reading the messages. Retention of messages was assessed through a post-visit quiz (*n*=217). A key finding was that visitors exposed to eight messages did not retain any more new knowledge than those who had read just two messages even though they would spend more time reading. In addition, the authors found that while the topographic map did attract visitors to the message board, it did not facilitate attention being paid to the messages. Not surprisingly trailside message boards are not an effective means of communicating with horse riders, who will perhaps find it difficult to stop at such places. Interpretive signs are not always effective. For example, Buckley (2004) reports how Pojar *et al.* (1975) found that even illuminated and animated warning signs did not reduce roadkill of deer: drivers only slowed down when they saw dead deer carcasses on the roadside.

The development of general codes of practice can be conceptualised as an overarching dimension of education and interpretation. They can perhaps best be viewed, in Marion and Reid's terms, as 'moral appeals' to those visiting and/or using 'natural' areas. Parker (2006, p. 1), for example, describes the UK's Country Code as 'an attempt to pursue a particular moral project and an effort to influence behaviour through design of a particular regime of conduct'. Sociological analysis of such codes has noted their important role in behaviour change, but analysis of their development has highlighted how they can become a vehicle for placating various competing actors and constructing particular boundaries around citizenship (Parker, 2006, 2007), rather than providing understanding of the processes necessary to generate a widely shared vision of acceptable behaviour.

# Discussion

In this section we make some observations about the limitations, strengths and framing of the evidence reviewed above, with the objective of illustrating its usefulness to forest managers.

## Quality and scope of literature, and its relevance to the UK forest context

In this study we have focused our attention on literature which identifies disturbance impacts of recreational activities. Remarkably few studies have been conducted in the UK and therefore much of the evidence relating to impacts and species encountered in the UK has been generated by research done in Europe (e.g. Finland, Sweden, Switzerland, Spain and Belgium) and further afield (e.g. USA and Australia). Forest environments do receive attention, often focusing on protected areas and sensitive habitats but also including a number of studies on urban woodlands. Moreover, much of the research on recreational disturbance relates either to trampling of vegetation or there is a considerable focus on the impact on bird species. Various studies and reviews note this focus on birds (e.g. Green and Giese, 2004; Higginbottom, 2004; Taylor *et al.*, 2005).

The results present a range of evidence highlighting how species are impacted through recreational use although many of the findings reported are possibly too detailed and context specific for the average manager to use meaningfully. Nevertheless, it does show that habitats can suffer from reduced plant and vegetation cover, plant damage and abrasion reducing growth and increasing premature leaf loss, reduced plant genetic and species diversity, modification of soil properties, soil removal and compaction, surface litter reduction, and damage to lichens and mosses. Wildlife can be crushed, hit and killed or disturbed through human or mechanical noise and/or close encounters. Recreational activities that interfere with feeding, breeding, travelling or resting behaviour can induce an alert or flight response affecting energy balances, social behaviour, increased vulnerability of the young or nest predation.

In some studies, human disturbance is implicated in impacts on bird species, but not observed or assessed directly. Liley and Clarke (2003), for example, analyse the relationship between nightjar density and surrogate measures of human density (such as number of buildings), which leads them to 'suggest', albeit 'tentatively', that reduced nightjar density is 'at least partly due to actual human presence on the heathlands and, as such, human disturbance is potentially a problem for this species'. Summers *et al.* (2004) move from their finding that some capercaillie tended to use trees away from tracks and roads to suggest that 'human disturbance may be displacing capercaillie and reducing the amount of woodland that can be fully occupied' (p.66). They subsequently conclude that track removal or closure may be beneficial for capercaillie. In an older study, Jackson and Jackson (1980) infer a link between good weather and increased use of heaths by holidaymakers, and consequent 'disturbance' of lapwings. None of these studies observes or measures actual human activities, presence or disturbance in the study areas, and are therefore of limited value in understanding links between recreation and wildlife disturbance. Rather, they demonstrate that the assumption of negative relationships between recreation and wildlife are a 'default' position.

## Isolating recreational disturbance from other disturbances

Forest managers need to be aware of the difficulty in isolating disturbance caused by recreation from natural disturbance and that caused by other human activities. Understanding the particular cause(s) of disturbance is, of course, essential if managers are to avoid or mitigate the impacts. The literature we have reviewed is one part of a wider set of literature describing disturbance of wildlife and natural areas by a range of human activities. Within the forestry literature there is a considerable focus on the disturbance impacts of forestry operations (e.g. timber harvesting). This general point has a number of implications for our study and the wider understanding of human disturbance. Disentangling the disturbances caused by these different activities can be problematic. In certain ways the distinction between sources of disturbance seems arbitrary, and somewhat unnecessary. For example, measuring the flight distance caused by noise generated by recreational vehicles or harvesting vehicles may be expected to yield similar results. We have included various studies of 'human disturbance' more generally within our review, but excluded many focused explicitly upon non-recreational activities. We did not identify any studies that discussed the impacts of recreation on wildlife management activities such as accidental disturbance of deer during stalking or damage to traps. Further investigation around this topic is recommended. However, it is vital to note that the social dimensions of these activities (such as likely behaviours and/or how information is understood and used), and therefore the legitimate management responses, will vary considerably. This makes the absence of social scientific analysis of these problems particularly apparent and problematic.

Another dimension emerges from the consideration of climate change as affecting wildlife and natural areas. Not only is climate change likely to affect people's recreational activities and patterns thereof, and in some locations exacerbate existing impacts from recreation (McEvoy *et al.*, 2008), but also climate change can itself be conceptualised as a cause of 'disturbance' (perhaps Type 2 - habitat change) which has the potential to affect every environment. This raises some profound questions relating to distinctions between 'human' and 'natural' environments: a dichotomy which, philosophically, has always been at the core of recreation ecology as a field.

The conceptualisation of wildlife habitat as somehow 'natural' areas in which humans (and their effects) are out of place permeates the recreation ecology and associated literature (and environmental and conservation literature beyond). It is particularly apparent in the use of terminology such as human 'intrusion' into wildlife habitat (e.g. Gutzwiller *et al.*, 1998, Gutzwiller, Riffell and Anderson, 2002; Gutzwiller and Riffell, 2008). A legitimate question is why should we treat wildlife disturbance by humans any differently from (i.e. more or less legitimate) disturbance by other wildlife? Prey species behaviour is fundamentally conditioned by predator species behaviour, a point which is perhaps made most explicitly by the ecology literature on the 'landscape of fear' concept (Laundré, Calderas and Hernández, 2009; Laundré, Hernández and Ripple, 2010; Manning, Gordon and Ripple, 2009). Anthropogenic disturbance of wildlife can be conceptualised in exactly this way and this can act to blur the boundaries around the study of 'disturbance' - and the legitimacy of responding to it.

In a corollary effect, such disturbance has been shown to have a positive effect on prey species through disturbance and displacement of *their predator* species - including a study of one UK forest species. Ibanez-Alamo and Soler (2010) conclude that disturbance by researchers ('investigators') 'significantly reduces nest predation' on blackbirds, leading them to suggest that blackbird predators may avoid disturbed places. This is an important finding, and very few studies investigate the impact of disturbance on predator behaviour. One exception, although not in a forest context, is Leighton, Horrocks and Kramer (2010), which investigated the impact of human disturbance upon the use of hawksbill sea turtle nesting habitat by an important predator species - mongooses. This study showed that human activity 'substantially decreased mongoose use of nesting habitat' and could thus reduce predation of nests by around one-third to one-half (range 29%-56%). The greatest effects were had at low visitor numbers.

## Impacts – physically similar, socially diverse

Given the literature's tendency to analyse disturbance physically (i.e. by focusing on the mechanics of trampling impact and responses to noise), it is useful to consider to what extent it is productive to analyse different recreational activities as distinct from one another and, thus, what is missed by current analysis. Certainly if we adopt Liddle's (1997) classification then there are several overlapping characteristics of disturbance relating to the most popular recreational activities conducted in forests. Type 1 disturbance where activities invoke an anti-predator response are identified in the literature on walking, mountain biking, off-road vehicle use, camping, skiing, nature watching and events such as paintballing and orienteering. Type 2 disturbance involving habitat destruction or modification through, for example, trampling are a feature of all of the activities identified in this review, while mountain biking and off-road vehicle use most typify Type 3 disturbance involving the capture or killing of wildlife (we do not cover hunting in this review which can clearly have this type of impact). In this sense there is no need to analyse the walker (and their boots) separately from the cyclist (and their tyres). Walking, horse riding and off-road vehicle use are all identified as potentially spreading invasive species, pests and diseases.

However, this analytic framework, and thus field, largely misses the potentially substantial social and cultural differences between recreationalists and their activities. These factors drive behaviour and thus the impacts of recreational disturbance in forests and woodland environments, the understanding of which is so crucial for managing disturbance. People choose to pursue different activities, at different times of the day, week and year. People's perceptions of rules and regulations affect how and when they pursue activities. An individual's personal values affect what they deem acceptable behaviour and what constitutes environmental impact. As impacts on forest species vary in this way it is important to know what types of activities occur in forest settings (Sun and Walsh, 1998) and their social or 'human' dimensions. This review illustrates that currently there is a dearth of knowledge on these dimensions and so it is difficult to make judgements on their relationship with disturbance impacts. Much more is needed here to improve understanding of social and cultural factors as drivers of impact that underpin management responses.

## Balance between disturbance and benefits of recreational use

In our Introduction we noted the demand placed on land managers, particularly in the public sector, to balance various societal needs and benefits against each other. In this review, we identified no studies which sought to assess the balance between the benefits gained from outdoor recreation and the disturbance of wildlife and the potential conservation dis-benefits of this. This is an important area for further research given the already noted (often implicit) tendency within recreation ecology to frame human influences on 'natural' areas as negative (i.e. 'disturbance'; 'intrusion') and/or 'unnatural'. Clearly human presence in natural settings is not an exclusively negative phenomenon as substantial social, cultural, psychological and health benefits can be obtained.

Management frameworks, such as 'Limits of Acceptable Change' (Stankey *et al.*, 1985) do recognise the need to have clear objectives for a recreational site in order to set the boundaries of acceptable management and assess its effectiveness. However, little attention, if any, has been given to assessments of, or tools for understanding, the dynamic relationship between 'costs' and 'benefits'.

## Recreationalists' perceptions of behaviour and impacts

Moscardo and Saltzer (2004 citing Cordell *et al.*, 1999) highlight that there are four sets of features that are associated with humans in the natural environment: (1) Interactions (e.g. the range of activities in natural environments); (2) Demand for the activities; (3) Values (e.g. that users attach to seeing wildlife); and (4) Perceptions or what people believe and know. The authors state, 'there are a number of different ways in which humans can interact with natural environments. In order to manage those interactions it is important to understand the nature and extent of the interactions and the forces that drive and shape them' (p. 170). For example, people's perceptions on how their recreational pursuits affect wildlife may influence their behaviour. Therefore, understanding user preferences and the range of perceptions, attitudes and behaviour would be relevant for managers (Symmonds, Hammett and Quisenberry, 2000; Taylor and Knight, 2003). The Recreational users' perspectives section on p.22 highlights the number of studies that attempt to compare the impacts of different recreational groups on wildlife. However, recreational users generally hold other users responsible for disturbance. Mountain bikers, horse riders and off-road vehicles were the most negatively viewed but most users were not fully aware of the impacts of their own recreational activities. Moreover, findings suggest that in some cases recreational users do not believe or care that they may be having an impact. The one study (Taylor and Knight, 2003) where potential management measures were rated showed that people were generally not supportive of restrictions on their activities. Nevertheless, Higginbottom (2004) suggests that it is most effective to target management primarily at the people rather than the wildlife. We found very little information that would usefully address important key questions around how social phenomena affect the type and scale of impacts (e.g. holiday periods, crowding), and what affects recreational users' behaviour in natural areas (e.g. knowledge, understanding and perception of 'rules'; signs and interpretation). There is a need to acknowledge that user groups are made up of individuals and there will be internal variability (i.e. all mountain bikers do not think and behave in the same way). Studies on the impacts of management responses on recreational users' perceptions of impact and actual behaviour are also needed.

## Management options

A range of options have been identified which relate to management of sites (e.g. habitat maintenance, screening) and people (e.g. buffer zones and other restrictions, regulations). Broad management frameworks are provided by, for example, Stankey *et al.* (1985) and Knight and Gutzwiller (1995). Restrictive management options are unlikely to be popular with recreational users and some authors have advocated low-impact educational approaches aimed at persuading users to behave appropriately or to encourage acceptance of essential management responses. However, as Higginbottom (2004) has noted, little progress has been made on determining the effectiveness of various management actions. Interdisciplinary and integrated research is needed to identify acceptable levels of impact, and what management options are most effective in mitigating recreational user impacts on certain wildlife, as well as which of these options are considered socially acceptable, and by which individuals and groups (Kazmierow, Hicking and Booth, 2000; Rodger, Moore and Newsome, 2010). More examples are needed of what management actions work, in which context, why and how?

## Future research needs

Our review has revealed considerable evidence relating to the disturbance of wildlife by recreational activities; however, substantial knowledge gaps remain. In our analysis above we focus primarily on some of the social dimensions of disturbance and go on to highlight associated evidence gaps below. However, it is critical first to note the dearth of basic ecological studies of wildlife disturbance in UK forests. We therefore remain largely ignorant in relation to some vital aspects of this debate. We have little or no knowledge regarding, for example, whether the vertical structure of forests increases or reduces disturbance. Do different densities of woodland understorey affect disturbance? In what ways are the different species assemblages associated with conifer and broadleaf forest types differently affected by recreation? A very few studies exist (or are ongoing) in relation to protected species in forests (e.g. capercaillie); however, the vast majority of species of conservation concern in UK forests remain unstudied in this regard. Little work has been done linking the success or failure of these species to the ecological conditions created by the recreational use of forests. Unless more compelling evidence is generated, debates about links between recreation and wildlife disturbance will continue to be based on uncertain, and sometimes conflicting, assumptions.

While discrete sociological and ecological research can clearly contribute positively to filling gaps in current knowledge, we would argue there is an urgent need for integrated interdisciplinary studies that link ecological impact studies on flora and fauna with social data on recreationalists' perceptions, attitudes and behaviour and support for actions in managing recreational disturbance (see Taylor and Knight, 2003). Addressing the following existing social evidence gaps would support managers in balancing public recreational access with nature conservation. We suggest that such studies are carried out across a wide range of species and forest types and not just those that have designated protection. This will widen the scope of our understanding of recreational disturbance leading to more effective visitor profiling and greater knowledge of the demand for different recreational activities and their potential or actual impacts. Suggested questions include:

1. How do specific recreational activities vary socially (i.e. change in social factors such as cultural norms) and how does this relate to disturbance?
2. How does recreationalists' knowledge and behaviour relate to wildlife disturbance?
    - Which 'knowledge networks' do people draw upon to inform themselves, if at all, of their impact on wildlife?
    - What is the role of social networks and activity groups in reducing wildlife disturbance?
    - How do these factors vary between groups?
3. How do recreationists respond to information on disturbance caused by recreation?
4. How does the existence and implementation of 'rules and regulations' relate to recreational disturbance of wildlife?
    - Which 'rules' prevent or promote disturbance of flora and fauna?
    - Can existing governance mechanisms, such as the permit system, be used more effectively to reduce disturbance?
    - What impact do less formal governance structures have on promoting behaviour that has minimal (or no) impact on wildlife?
5. How can we monitor the level of 'user compliance' (i.e. the effectiveness) of formal and less formal governance mechanisms?

# Conclusion

While woodlands and forests are important places for public recreation, land managers have to balance the public benefits derived from forest-based recreation with conservation of biodiversity and other wildlife management requirements. Understanding the particular cause(s) of disturbance is essential if managers are to avoid or mitigate the impacts. Thus, the objective of this review was to gather up-to-date evidence on the impact of recreational activities on flora and fauna and habitat in UK forests. We focused our attention on literature based around disturbance impacts of recreational activities acknowledging that this is only one part of a wider set of literature describing disturbance of wildlife and natural areas by a range of human activities.

This review illustrates how recreation in forests is conceptualised by the literature as an almost purely physical phenomenon, not as a human activity. This leaves significant gaps in the understanding and knowledge resources available to forest managers charged with balancing demands for recreation, nature conservation and other needs. We found that few studies have been conducted in the UK and therefore this review relies to some degree on research from other countries but with relevance to UK forests. Moreover, although over 450 sources were identified relating specifically to the disturbance of flora and fauna by recreational activities such as walking, mountain biking, horse riding, vehicle use, camping and nature watching, the majority do not report research undertaken in forests or woodlands. Of the literature reviewed much was related specifically to walking and/or to impacts of recreational activities on soils and vegetation (e.g. trampling) and especially birdlife. However, key impacts of disturbance common among all the recreational activities were: (i) habitat change; (ii) 'flight'; or (iii) the introduction of invasive species, pests or diseases. Protected and 'wilderness' areas are a major focus of this field of research, although other woodlands also receive attention - such as those around urban areas.

The importance of understanding recreational user preferences and the range of perceptions, attitudes and behaviour has been highlighted in this review, particularly in the context of linking activities with disturbance impacts. However, the literature generally does not examine the social dimensions of recreational impact. While we were able to identify, to some extent, the level and range of disturbance impacts on flora and fauna from recreational activities, there was essentially very little that could usefully improve our understanding of why and when users recreate in particular natural environments and what influences their behaviour. Robust evidence relating to how recreational users understand or perceive their own and others' impacts on wildlife is also very sparse.

Much of the literature reviewed provided management recommendations but only a limited number of studies directly or systematically address the management options available. These were briefly discussed in the Managing impacts section (p.24) and include physical and natural barriers as well as marketing and educational programmes. However, there is little or no evidence available on the effectiveness of management activities in mitigating negative impacts of recreational use on flora and fauna or how they have influenced the behaviour of different user groups. Overall, robust social evidence on recreational users' knowledge, attitudes and behaviour and their potential impact on wildlife through disturbance is lacking, yet it is clear that such information is crucial for the development of appropriate and effective management strategies. A good starting point in a UK forestry context would be a small number of interdisciplinary case studies integrating social and ecological research across geographical contexts which encompass a range of recreational users. These should include 'typical' UK forests which feature landscape, habitat and species diversity, along with social diversity.

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Forests are popular places for recreation, but some activities can have negative impacts on wildlife. Land managers have to balance delivery of the social and economic benefits derived from outdoor recreation with nature conservation objectives. This literature review provides an overview of potential disturbance issues and a guide to the evidence on impacts from walking, cycling, horse riding, off-road vehicle use, camping, and other recreational activities that take place in forests. Greatest attention has been directed towards walking, and impacts on soils, vegetation and birdlife. Much of the literature focuses on the physical characteristics of disturbance but there is little social scientific analysis of recreational users, for example on how their values and awareness relate to disturbance, or wider social factors that influence where, when and whether impacts occur. An holistic approach to understanding and managing the interaction of recreation and forest wildlife is needed, which links ecological studies with social data.



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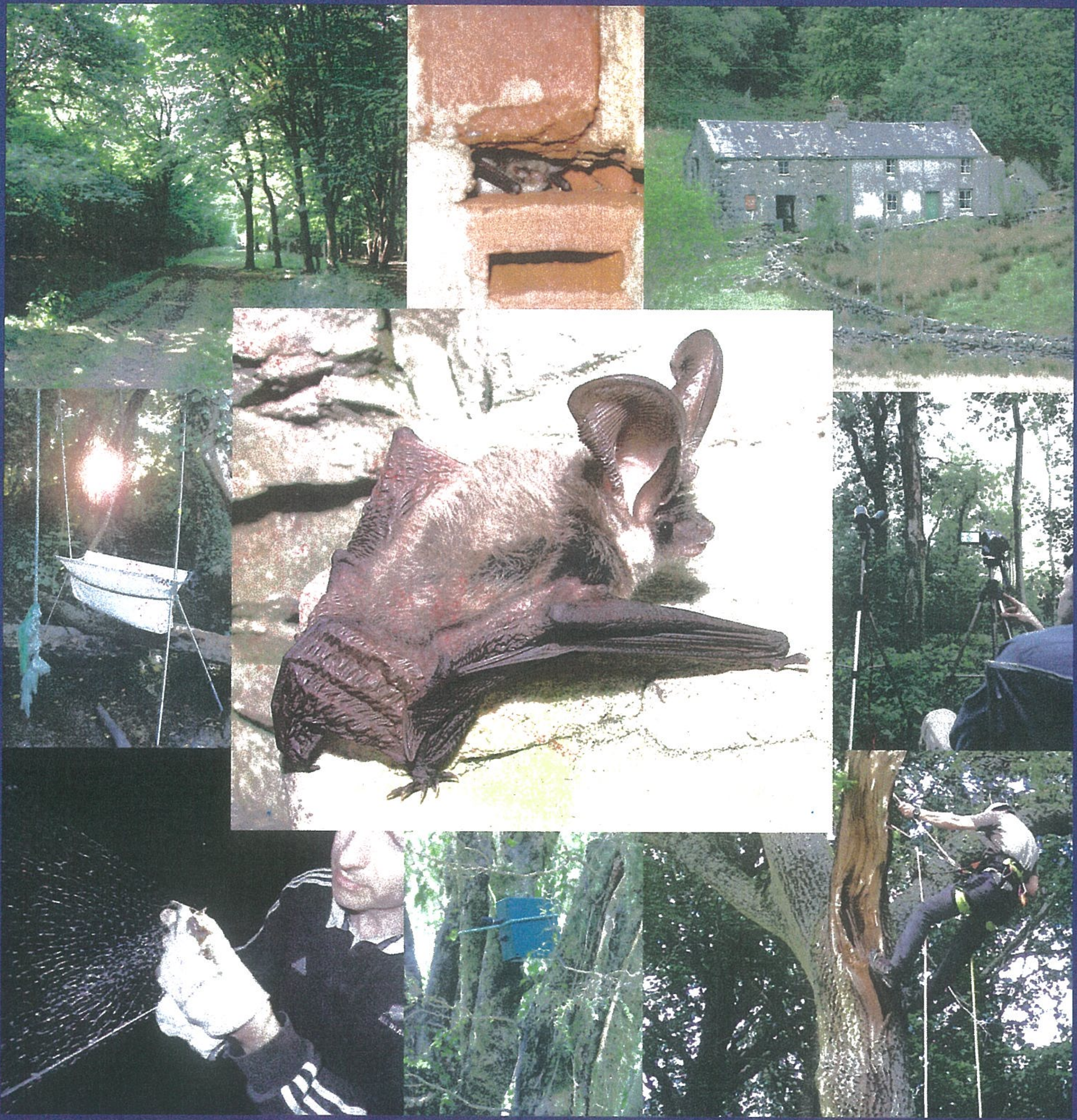
Bat Conservation Trust

# Bat Surveys for Professional Ecologists

## Good Practice Guidelines



3rd edition

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CIEEM Chartered Institute of Ecology and Environmental Management

CIEEM welcomes the publication of the third edition of the Bat Surveys for Professional Ecologists: Good Practice Guidelines. Like all good guidance it avoids being unnecessarily prescriptive in its recommended approaches and recognises the importance of suitably competent professionals applying their professional judgement appropriately and with justification when circumstances dictate that it is necessary to do so. Accordingly CIEEM is pleased to endorse these new Guidelines as good practice guidance for all those undertaking bat surveys.

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Centre photo: *Greater long-eared bat* – Richard Crompton, Wildwood Ecology Ltd.

Bat Conservation Trust

# Bat Surveys for Professional Ecologists

## Good Practice Guidelines (3rd edition)

## Foreword

Bat Surveys for Professional Ecologists: Good Practice Guidelines (3rd edn) builds on previous editions using feedback from general comments to the Bat Conservation Trust and a public consultation, following the publication of the second edition in 2012. Representatives of developers, ecological consultancies, local authorities, licensing authorities, academic institutions and voluntary bat workers have provided comments, which have been collated and considered in the writing of this edition. The comments highlighted areas of the existing guidelines that needed clarification; new subject areas that should be added; and necessary updates following changes in legislation, licensing, policy or the publication of new research. A Technical Review Board, consisting of a wide range of stakeholders, has reviewed this edition. This document is available to purchase as a hard copy, or can be downloaded from www.bats.org.uk. This edition will be subject to review after two years; any comments should be sent to surveyguidelines@bats.org.uk.

Julia Hanmer

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Joint Chief Executive

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## Acknowledgements

This publication has benefitted greatly from the input of a large number of people. In particular, the Bat Conservation Trust would like to extend its thanks to the new contributing authors, Technical Review Board and technical reviewers/contributors, whose names are all listed on the next page. All of these people gave significant amounts of their time free of charge to write new material and review draft versions of the document.

BCT would like to thank all those who responded to the consultation held in 2013 and those who have provided comments to BCT since the publication of the second edition of these guidelines. All comments and suggestions were considered and many were incorporated into this version. Space precludes us from listing everyone here but their input was invaluable.

Several members of BCT staff have contributed a great deal to this document in a variety of ways, including Kate Barlow, Katherine Boughey, Pete Charleston, Jo Ferguson, Lisa Hundt, Helen Miller and Carol Williams, who provided a sounding board, wrote or discussed sections of the text, and reviewed draft versions of the document.

Many thanks to our sponsors for providing funding towards the printing costs, thereby enabling proceeds from the sale of this document to go towards bat conservation.

Many others have helped with the production of this document and it has not been possible to list everyone by name. We would like to thank you all for your time and expertise.

**Editor**
Jan Collins (BCT)

**Contributing authors**

Jan Collins (BCT): all chapters/sections except those listed below.
Pete Charleston (BCT): *Section 1.2.1, Legislative context.*
Ian Davidson-Watts (Davidson-Watts Ecology Ltd): *Chapter 9, Advanced licence bat survey techniques and Section 10.4, Analysis of bat radiotelemetry survey data.*
Steve Markham (Marquis & Lord): *Section 10.3, Analysis of bat activity survey data; Appendix 7, Introduction to data analysis; Appendix 8, Worked examples of statistical analysis, plus various shorter sections on sampling and analysis.*
Lisa Kerslake (Swift Ecology Ltd): *Appendix 4, Protocol for bat dropping collection for DNA analysis.*

**Technical Review Board**

The role of this Technical Review Board was to review a draft of Bat Surveys for Professional Ecologists: Good Practice Guidelines (3rd edn) produced by the authors listed above. The Technical Review Board provided comments on the draft and contributed further through verbal and written discussions on key areas. All comments and discussions were taken into account in producing the final version of these guidelines but, where consensus could not be reached, BCT took the final editorial decision. All authors of Bat Surveys – Good Practice Guidelines, 2nd edn (Hundt, 2012) were included in this Technical Review Board. Members of the Technical Review Board and their affiliations are listed below.

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**Specialist reviewers/contributors**

Specialist reviewers/contributors were brought in to review and contribute to specific technical sections of these guidelines. They provided comments (including suggested alternative text) on drafts that were taken into account in producing the final version of these guidelines but, where consensus could not be reached, BCT took a final editorial decision. Specialist reviewers/contributors, their affiliations and the sections they reviewed/contributed to are listed below.

John Altringham (Leeds University): *Section 7.3, Swarming surveys.*
Ian Davidson-Watts (Davidson-Watts Ecology Ltd): *Section 7.3, Swarming surveys.*
Daniel Whitby (AEWC): *Chapter 8, Advanced licence bat survey techniques; Section 7.3, Swarming surveys.*

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# List of abbreviations used in text

| | |
|---|---|
| ASSIs | Areas of Special Scientific Interest (Northern Ireland designation) |
| BCA | British Caving Association |
| BCT | Bat Conservation Trust |
| BSI | British Standards Institution |
| BS42020 | British Standard 42020:2013 Biodiversity. Code of practice for planning and development |
| CCW | Countryside Council for Wales (now Natural Resources Wales) |
| CIEEM | Chartered Institute for Ecology and Environmental Management (formerly the Institute for Ecology and Environmental Management) |
| CITB | Construction Industries Training Board |
| CSCS | Construction Site Certification Scheme |
| CSZ | Core Sustenance Zone |
| DCLG | Department for Communities and Local Government |
| DOE | Department of the Environment (in Northern Ireland) |
| EC Habitats Directive | Council Directive 92/43/EEC 1992 on the conservation of natural habitats and of wild fauna and flora |
| EcIA | Ecological Impact Assessment |
| EIA | Environmental Impact Assessment |
| EN | English Nature (now Natural England) |
| EPS | European Protected Species |
| FC | Forestry Commission |
| FCS | Favourable Conservation Status |
| HRA | Habitats Regulations Assessment |
| HSE | Health and Safety Executive |
| IEEM | Institute for Ecology and Environmental Management (now the Chartered Institute for Ecology and Environmental Managment) |
| JNCC | Joint Nature Conservation Committee |
| LBG | local bat group |
| LPA | Local Planning Authority |
| LRC | Local Records Centre |
| LWT | local Wildlife Trust |
| MAGIC | Multi Agency Geographic Information for the Countryside |
| MEWP | mobile elevating work platform |
| NBN | National Biodiversity Network |
| NE | Natural England (formerly English Nature) |
| NERC Act | Natural Environment and Rural Communities Act, 2006 |
| NFBR | National Forum for Biological Recording |
| NGO | non-governmental organisation |
| NNR | National Nature Reserve |
| NPPG | National Planning Policy Guidance |
| NRW | Natural Resources Wales (formerly the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales) |
| PIT | passive inductor transponder |
| PPE | personal protective equipment |
| PRF | Potential Roost Feature |
| RIBA | Royal Institute of British Architects |
| SAC | Special Area of Conservation |
| SE | Scottish Executive |
| SNCO | Statutory Nature Conservation Organisation |
| SNH | Scottish Natural Heritage |
| SSSI | Site of Special Scientific Interest |
| ZoI | zone of influence |

Chapter 1

# Background



## 1.1 Introduction

### 1.1.1 Aim of the guidelines

This publication aims to provide good practice guidelines in relation to designing and undertaking bat surveys; analysing the data collected during those surveys; and writing survey reports. The guidelines relate to professional bat surveys carried out to assess how proposed activities may impact bats. The guidelines aim to raise standards and increase the consistency of this type of work and ultimately lead to a greater understanding of bats and improvements in their protection and conservation.

### 1.1.2 Intended audience

These guidelines are intended primarily for professional ecologists carrying out bat surveys and writing reports in relation to proposed activities that could impact bats. They may also be useful to:

- developers commissioning bat surveys and reports from ecologists in relation to development; and
- planners, ecologists and policy-makers working for local authorities, licensing authorities and non-governmental organisations (NGOs), who are responsible for reviewing and assessing the implications of professional bat surveys.

### 1.1.3 What the guidelines do not aim to do

The guidelines do not aim to either override or replace knowledge and experience. It is accepted that departures from the guidelines (e.g. either decreasing or increasing the number of surveys carried out or using alternative methods) are often appropriate. However, in this scenario an ecologist should provide documentary evidence of (a) their expertise in making this judgement and (b) the ecological rationale behind the judgement.

Equally, it would be inappropriate for someone with no knowledge or experience to read these guidelines and expect to be able to design, carry out, interpret the results of and report on professional surveys as a result, simply following the guidelines without the ability to apply any professional judgement. Training and experience is necessary to carry out all of the surveys described in these guidelines and interpret the survey results appropriately (see Section 2.5.1).

British Standard 42020 Biodiversity. Code of practice for planning and development (British Standards Institution (BSI), 2013, hereafter referred to as BS42020) is relevant to the planning process, other consented development and proposals involving the management and use of land. This states that:

- 'any individual dealing with ecological issues at any stage of the planning application process should be able to demonstrate that they have sufficient technical competence and experience to carry out the particular tasks and activities for which they are responsible in the role that they are performing' (BS42020; Clause 4.3.2);
- 'an explanation, with evidence, of the assessment and decision-making process and the reasons for a particular course of action or piece of advice should be clearly documented and made available where required and/or necessary' (BS42020; Clause 4.4.3); and
- 'it is especially important to provide evidence of how professional judgement has been applied where ecological work does not follow, in full or in part, the recommendations set out in national good practice guidelines' (BS42020; Note for Clause 4.4.3).

The guidelines should be interpreted and adapted on a case-by-case basis according to site-specific factors and the professional judgement of an experienced ecologist. Where examples are used in the guidelines, they are descriptive rather than prescriptive.

The guidelines do not aim to provide information on carrying out Ecological Impact Assessments (EcIAs). However, the survey work undertaken should be designed to answer questions that the impact assessment process will generate. Frequent reference is therefore made to the potential impacts of a project and associated relevant questions. *Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal* (Chartered Institute of Ecology and Environmental Management (CIEEM), 2016) provides more information in this respect.

The guidelines do not aim to provide information on designing strategies to mitigate for impacts on bats. The *Bat Mitigation Guidelines* (Mitchell-Jones, 2004) or resources such as the Bat Conservation Trust's (BCT) Roost website can be used for this purpose.[1]

Although the survey techniques described are also often used in bat conservation or research, the guidelines have not been written for these purposes and should not be used to design such surveys. Surveys for bat conservation purposes are described in the *Bat Worker's Manual* (Mitchell-Jones and McLeish, 2004) and surveys for research purposes should be bespoke, designed according to the specific questions the research is intended to answer.

[1] http://roost.bats.org.uk/

Chapter 9, on advanced licence bat survey techniques, does not cover the use of bat rings/bands used for long-term monitoring programmes or other techniques usually associated with research such as light-tagging or passive inductor transponder (PIT) tags as these are not generally considered appropriate for surveys associated with developments. For further information on these methods, refer to Kunz and Parsons (2009).

In these guidelines, a survey is defined as a sampling activity in which a wide range of variables are measured to describe a site or an area. Surveying is distinct from monitoring, which involves repeated sampling, either year-on-year or periodically, usually to quantify changes over time or to assess whether a particular objective or standard has been attained. These guidelines do not include surveys carried out for monitoring purposes. Some information about monitoring the success of mitigation measures is provided in the *Bat Mitigation Guidelines* (Mitchell-Jones, 2004).

Please note that due to the delay in publication of the National Bats and Wind Turbines Project report, a specific chapter on wind farms is not included in this edition. Chapter 10 of the second edition of these guidelines (Hundt, 2012) will stand until new guidelines are available for this project type.

Finally, this edition of the guidelines does not include specific advice in relation to road and rail schemes, although the principles of survey design and execution do apply. Berthinussen and Altringham (2015) provide information on pre- and post-construction surveys of linear infrastructure schemes, designed specifically to assess the effectiveness of mitigation for bats crossing them.

## 1.2 Context for bat survey work

### 1.2.1 Legislative context

General, rather than comprehensive text on the legislation relating to bats and bat surveys is provided here. When dealing with individual cases, readers should consult the full texts of the relevant legislation and obtain legal advice if necessary. They should also check regularly for changes to legislation, guidance and case law. A summary of the relevant nature conservation legislation (correct at time of publication) is given in Table 1.1.

**Table 1.1 Summary of the main legislation pertaining to the protection of bats in the UK.**

| | Habitats Regulations (transposing the EC Habitats Directive) | Other nature conservation legislation |
|---|---|---|
| **England and Wales** | Conservation of Habitats and Species Regulations 2010 (as amended) | Wildlife and Countryside Act 1981 (as amended) |
| **Northern Ireland** | Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995 (as amended) | Environment (Northern Ireland) Order 2002 |
| **Scotland** | Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) | |

**The EC Habitats Directive and respective domestic legislation**
Annex II of the Council Directive 92/43/EEC 1992 on the conservation of natural habitats and of wild fauna and flora (EC Habitats Directive) lists animal and plant species of Community interest, the conservation of which requires the designation of Special Areas of Conservation (SACs); Annex IV lists animal and plant species of Community interest in need of strict protection. All bat species are listed in Annex IV; some are listed in Annex II.

In the UK,[2] the EC Habitats Directive has been transposed into national laws by means of the Conservation of Habitats and Species Regulations 2010 (as amended) (England and Wales),[3] the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) (Scotland)[4] and the Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995[5] (as amended).

Commonly the regulations are referred to as the Habitats Regulations.[6] They will now be referred to as such.

**Legal framework**
Although the precise wording of the legal protection afforded to bats differs between countries in the UK it all falls within a common framework making unlawful specific actions against bats but with differing emphasis on the state of mind needed to evidence offences. The legislation does not, in the main, mention bats except in annexes and schedules. The Habitats Regulations refer to specimens of European Protected Species (EPS). All species of bats found in the wild in the UK are EPS.

**Kill, injure, capture/take bats**
It is unlawful to kill, capture, injure or take a wild bat anywhere in the UK. In England, Wales and Northern Ireland the offence requires a deliberate action; in Scotland it requires a deliberate or reckless action. All offences of this nature are identified within the Habitats Regulations.

**Disturbing bats**
It is unlawful to disturb bats anywhere (roosts, flight lines or foraging areas) but only if the level of disturbance can be shown

[2] The EC Habitats Directive does not apply to the Isle of Man and the Channel Islands, which are part of the British Isles but not part of the UK.
[3] http://www.legislation.gov.uk/uksi/2010/490/contents/made
[4] http://www.legislation.gov.uk/uksi/1994/2716/made
[5] http://www.legislation.gov.uk/nisr/1995/380/contents/made
[6] In Scotland and Northern Ireland the Habitats Regulations have been amended on a number of occasions, most particularly in 2007.

to impair their ability to survive, to breed or reproduce, to rear or nurture their young, to hibernate or migrate or to affect significantly local distribution or abundance. In England, Wales and Northern Ireland the offence requires a deliberate action. In Scotland the offence requires a deliberate or reckless action. All offences of this nature are identified within the Habitats Regulations.

In Scotland it is also an offence in the regulations to deliberately or recklessly disturb a bat whilst it is occupying a place of shelter or protection. This offence does not require the level of disturbance to be significant.

In England and Wales it is also an offence under the Wildlife and Countryside Act[7] to intentionally or recklessly disturb a bat, whilst it is occupying a place of shelter or protection. A householder who disturbs a bat in its place of shelter or protection does not commit an offence if they first seek the advice of Natural England (NE) or Natural Resources Wales (NRW) and allow time for such advice to be provided. If the bat is in the living area of a dwelling house it is not an offence in any circumstance to disturb it. This provision does not apply to Scotland or to Northern Ireland.

**Harassing bats**
In Scotland only it is an offence to deliberately or recklessly harass a bat or a group of bats.

**Damage or destruction of roosts**
Throughout the UK it is illegal to damage or destroy a place used by a bat for breeding or resting. All offences of this nature are identified within the Habitats Regulations. This offence is unique in that it can be committed accidently. No element of intentional, reckless or deliberate action needs to be evidenced.

**Obstructing access to a breeding site or resting place**
In Scotland it is an offence under the regulations to deliberately or recklessly obstruct access to a breeding site or resting place of a bat or to otherwise deny a bat the use of such a place. In Northern Ireland it is an offence under the regulations to deliberately obstruct access to a breeding site or resting place used by a bat.

In England and Wales it is an offence under the Wildlife and Countryside Act to intentionally or recklessly obstruct access to any place used by a bat for shelter or protection. A householder will not commit an offence if he obstructs access to a bat roost in a dwelling house providing they first seek the advice of NE or NRW and allow them time to provide such advice. This defence does not apply in Scotland or to Northern Ireland.

**Possession and sale of bats**
Under the Habitats Regulations it is an offence to be in possession or control of a bat alive or dead (or any part of a bat or anything derived from a bat, although bat droppings are generally considered to be acceptable), or to transport a bat, to sell or exchange a bat or to offer to sell or exchange a bat taken from the wild.

It is an offence under the Wildlife and Countryside Act in England and Wales to offer or expose for sale any bat of a species listed in Schedule 5 and taken from the wild or to possess any bat or anything derived from a bat for the purposes of sale. To publish or cause to be published any advertisement offering to buy or sell a bat.

**Illegal methods for taking or killing bats**
The Habitats Regulations in all parts of the UK contain provisions prohibiting certain methods of taking or killing bats even when the activity itself has been licensed. The Wildlife and Countryside Act contains similar provisions that still apply in England and Wales.

**Offences relating to licensing**
Actions, which would otherwise be illegal, can be made lawful if licensed by the appropriate Statutory Nature Conservation Organisation (SNCO).[8] It is an offence anywhere in the UK to make a false statement in order to obtain a bat licence or to fail to comply with the conditions of a bat licence.

**Attempts and possession of items to be used to commit offences**
It is an offence in all parts of the UK to attempt to commit any criminal offence or to possess items to be used to commit offences identified in any of the legislation referred to above. Legislation throughout the UK is such that it may not be only those who are directly responsible for offences that are liable. In Scotland those who cause or permit offences are guilty as are those who aid or abet offences elsewhere.

**Defences**
It is not illegal anywhere in the UK:
- to take a disabled bat, for the sole purpose of tending it and releasing it when no longer disabled, as long as that person can show that it was not disabled unlawfully by them;
- to kill a bat, as long as that person can show that the bat was so seriously disabled, other than by their own unlawful act, that there was no reasonable chance of it recovering.

These defences, however, only apply in circumstances where there is no reasonable alternative, and when the act will not be detrimental to the maintenance of the species at a Favourable Conservation Status (FCS) in its natural range.

**Protected areas**
Some species of bat found in the UK (greater and lesser horseshoe bats, barbastelle and Bechstein's bat) are listed in Annex II of the Habitats Directive. This means that they can be listed as an interest feature of a SAC and therefore the reason why the SAC is designated. This means they are also a relevant consideration in a Habitats Regulations Assessment (HRA), which provides these species with additional legislative protection. The requirement for this is under Article 6 of the Habitats Directive.[9]

Across the UK Sites of Special Scientific Interest (SSSIs) and Areas of Special Scientific Interest in Northern Ireland (ASSIs) have been identified by the SNCOs. Some such sites have been notified for their bat interest. Legislation relating to such areas

[7] The Wildlife and Countryside Act 1981 has been amended on numerous occasions, in particular by the Countryside and Rights of Way Act 2004 (CROW) and the Natural Environment and Rural Communities Act 2006 (NERC).
[8] Natural England, Natural Resources Wales, Scottish Natural Heritage or Department of the Environment (in Northern Ireland).
[9] A HRA Handbook can be found at http://www.dtapublications.co.uk.

identifies criminal offences if bats are disturbed, if roosts are damaged or if certain operations are undertaken without consent in places notified for their bat interest. In England and Wales the appropriate legislation is the Wildlife and Countryside Act 1981 and in Northern Ireland the Environment (Northern Ireland) Order 2002. In Scotland the Nature Conservation (Scotland) Act 2004 creates and protects SSSIs although no sites have been designated for bats.

**Police and court powers**
A police constable in any part of the UK has the power, where he has reasonable cause to suspect that a person is committing or has committed an offence, to stop and search them, search or examine any relevant thing in their possession, and seize it. They can also enter land other than a dwelling house without a warrant, or enter and search a dwelling house with a warrant. Constables are empowered to take with them any person or any equipment needed to exercise their powers. Legislation in England and Wales provides a defence for police officers who commit certain offences during the course of their enquiries, otherwise their acts are authorised by a licence issued by the SNCOs.

Those found guilty of offences relating to bats can be sentenced to six month's imprisonment and fined. Recent legislation in England and Wales has removed the maximum amount of fine that can be imposed, and courts there now have the power to impose unlimited fines.[10] In Scotland and Northern Ireland maximum fines at present are set at £5000 but a penalty can be imposed for each animal involved. Courts have a wide range of other sanctions available to them, for example they can order forfeiture of anything used to commit offences or proceeds of crime orders can be made that allow for any profit arising from criminal activity to be confiscated.

**Interpretation of legislation**
Legislation throughout the UK commonly uses the words: intentional, deliberate or reckless. There is substantial legal opinion as to the meaning of each. Beyond this there have never been any stated cases relating to bats and the criminal law. As such there is little guidance as to the intent of the legislation, with few terms being defined. Commonly questions are posed as to how long bat roosts retain their legal protection when they cease to be used. Some guidance can be found in information produced by the European Union but this information has not been tested in criminal proceedings.[11]

### 1.2.2 Licensing

The two main types of licence relevant to these guidelines are survey licences (also known as science and education or conservation licences) and EPS licences (also referred to as derogation, mitigation or development licences). Both types of licence permit activities that could otherwise be an offence (see Section 1.2.1).

**Survey licences**
Survey licences are issued by the following licensing authorities:

- England: NE
- Wales: NRW
- Scotland: Scottish Natural Heritage (SNH)
- Northern Ireland: Department of the Environment (DOE)

**These licences do not cover the damage or destruction of a roost site for development; see instead European Protected Species (EPS) licences.**

Survey licences are issued to ecologists under the Habitats Regulations to permit them to undertake activities that could otherwise be illegal and lead to an offence, such as entry into a bat roost, temporary disturbance of bats during a survey (including endoscoping) and capture and handling of bats. Ecologists go through a period of training and peer review before being signed off for a licence by their trainer and/or referees. The possession of a survey licence is an indication that the surveyor has reached a minimum standard of training and experience (see Section 2.5.1), although this does not relate to impact assessment or the design and implementation of mitigation, enhancement and monitoring schemes.

Ecologists without a survey licence should not enter known roosts or sites where signs of bat presence (or possible bat presence) have been found. Even where no signs have been found, it is good practice for surveys of potential roost sites to be carried out by ecologists with a survey licence. If it is necessary for an ecologist without a survey licence to survey a building with bat roost potential he/she should immediately withdraw if evidence of bats is found in order for a licensed ecologist to complete the survey. Some surveys, such as emergence or activity surveys, do not require a licence because they do not cause disturbance to bats when undertaken correctly. Some Local Planning Authorities, however, have specific requirements regarding surveyors being licensed if carrying out bat surveys for planning purposes, so local requirements should always be checked.

Although a limited amount of trapping (using mist nets, harp traps and lures) is permitted under some survey licences, a relevant project licence is generally required for such activities and for attaching radio transmitters. Other marking methods, not covered by these guidelines, also require a licence, such as the fitting of tags or rings. A project licence is granted for specific species and numbers of bats, for specific dates and at a particular location. When applying for a project licence, the applicant needs to demonstrate that the level of disturbance is justified and that he or she has the necessary experience to undertake the work.

**Conservation licences**
Conservation licences may be issued to allow improvements to a bat roost site where the main purpose of the work is for conservation of the species at a specific site. These licences would normally only be issued for a specific proposal at a specific site and only for the duration of the work.

**Photography/filming**
A licence to photograph (including filming) bats is not required if the photography is an **incidental part of other licensed bat work** and it causes no extra disturbance above that caused by the licensed activities. Such photography includes:

[10] http://www.legislation.gov.uk/uksi/2015/664/contents/made
[11] http://ec.europa.eu/environment/nature/conservation/species/guidance/pdf/guidance_en.pdf

- non-flash photography (i.e. using only natural light or low-level artificial light such as a domestic torch or low-output LED) of roosting bats and of people carrying out licensed work in and around roosts;
- flash photography in roosts and hibernacula only when no bats are present;
- photography of bats caught at traps during survey work;
- flash photography of individual bats for identification purposes or of groups of bats for survey purposes; and
- the use of night vision/infrared/thermal imaging cameras to record roosting (as part of other licensed work) or emerging bats either without the use of further illumination or using infrared illumination (not a red filter).

These only apply where the licence holder considers that this would cause less disturbance than handling or prolonged illumination of bats. It is recommended that there is only one designated photographer at any one time to reduce disturbance.

Flash photography in occupied bat roosts or hibernacula, or entering bat roosts or hibernacula specifically for the purpose of photography (including filming), must be specifically licensed. As disturbing bats specifically for the purpose of photography is potentially very disturbing to bats, licences are only likely to be given where the licensing authority agrees there is a clear need for the photographs and only to experienced photographers who can demonstrate their ability to work efficiently with minimal disturbance to the bats.

**Class licences for surveying bats in England**
In England a class licensing system has been introduced for survey licences (issued for the purposes of science and education including research). These licences are for all bat-related activities (both voluntary and professional) outside of the NE volunteer bat roost visitor advice service. This includes:

- bat box checks;
- hibernation surveys;
- general survey work;
- professional survey work;
- use of harp traps, mist nets and acoustic lures for development survey purposes.

At present there are four levels of class licence. These are summarised below. The GOV.UK website should be consulted for further details.

- *Level one – to survey bats by observation only (licence WML-CL17) – Disturbance only.*

Surveying of bats by observation only (including the use of artificial light, in the form of torches but not endoscopes) for scientific, research or educational purposes, including informing development projects. This does not include surveys of hibernating bats.

- *Level two – to survey bats using artificial light, endoscopes, hand and hand-held static nets (licence WML-CL18) – Disturbance with handling.*

Surveying of bats using artificial light (e.g. torches), endoscopes, hand and static hand-held nets for scientific, research or educational purposes, including informing development projects. This includes surveys of hibernating bats.

- *Level three – to survey bats using artificial light, endoscopes, hand and hand-held static nets, mist nets and acoustic lures (licence WML-CL19) – Disturbance with handling and mist netting.*

Surveying of bats using artificial light (e.g. torches), endoscopes, hand, static hand-held nets, mist nets and acoustic lures for scientific, research, or educational purposes, including informing development projects.

- *Level four – to survey bats using artificial light, endoscopes, hand and hand-held static nets, harp traps and acoustic lures (licence WML-CL20) – Disturbance with handling and harp trapping.*

Surveying of bats using artificial light (e.g. torches), endoscopes, hand, static hand-held nets, harp traps and acoustic lures for scientific, research, or educational purposes, including informing development projects.

**European Protected Species (EPS) licences**
EPS licences are issued by the same licensing authorities as survey licences (see previous section). EPS licences are issued under the Habitats Regulations only after three tests have been satisfied in relation to the proposed action, as follows:

- the proposed action must be for the purpose of preserving public health or public safety or other imperative reasons of overriding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment; and for preventing serious damage to property;
- there is no satisfactory alternative to the proposed action; and
- the action authorised will not be detrimental to the maintenance of the species concerned at a FCS in their natural range.

A FCS is defined in the Habitats Directive as follows (from JNCC, 2007):

> 'i. Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
> ii. The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
> iii. There is, and will probably continue to be, a sufficiently large habitat to maintain its population on a long-term basis.'

In order for these tests to be correctly applied, it is essential that baseline survey information of a sufficient quantity, quality and standard is supplied. Without this survey information, a licence may not be granted.

Information on when a licence is required, how to apply for a licence, and maintaining the FCS of a species, can be found on the relevant licensing authority websites.

In 2014, Natural England announced the introduction of a Low Impact Bat Class Licence scheme. Ecologists can apply to become a Registered Consultant to use this type of licence, which is for low impact type cases.

### 1.2.3 Planning policy context

Government policy guidance for biodiversity and nature conservation throughout the UK is provided in the following planning guidance and statements, which are current at the time of writing:

- England:
  - National Planning Policy Framework 2012 (DCLG, 2012)
  - Government Circular 06/2005: Biodiversity and geological conservation – Statutory obligations and their impact within the planning system (DCLG, 2005)
  - Circular 02/99: Environmental impact assessment 1999 (DCLG, 1999)
- Northern Ireland:
  - Planning Policy Statement 2: Natural Heritage (DOENI, Planning Policy Group 2013)
  - Planning Policy Statement 18: Renewable Energy (DOENI, Planning and Environmental Policy Group 2009)
- Scotland:
  - Scottish Planning Policy (Scottish Government, 2014)
- Wales:
  - Planning Policy Wales 2014 (Welsh Government, 2014)
  - Technical Advice Note 5 Nature Conservation and Planning (Welsh Government, 2009)

In addition to the national policy guidance outlined above, regional and local planning policies should be consulted and other country-specific guidance, such as NE's standing advice to Local Planning Authorities (LPAs)[12] may also be relevant.

Government planning policy guidance throughout the UK requires LPAs to take account of the conservation of protected species when considering and determining planning applications. This biodiversity duty is imposed in England and Wales through the Natural Environment and Rural Communities (NERC) Act 2006, which states that 'every public authority must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity'. The Nature Conservation (Scotland) Act 2004 states that 'it is the duty of every public body and office-holder, in exercising any functions, to further the conservation of biodiversity so far as is consistent with the proper exercise of those functions'.

Planners are required to consider protected species as a material consideration when assessing a development proposal that, if carried out, would be likely to result in harm to the species or its habitat. This requirement has important implications for bat surveys as it means that, where there is a reasonable likelihood of bats being present and being affected by the development, surveys must be carried out before planning permission is considered.

Adequate surveys are therefore required to establish the presence or absence of bats, to enable a prediction of the likely impact of the proposed development on them and their breeding sites or resting places and, if necessary, to design mitigation, enhancement and monitoring measures.

The term 'development' used in these guidelines includes activities and proposals that could impact bats. In planning terms this includes activities requiring outline and full planning permission but also those that meet the criteria for permitted development, require listed building consent and require prior approval to demolish.

Further details on the standard of information required to assess a planning application is detailed in Clauses 6 and 8 of BS42020 (BSI, 2013). In particular, 'The final report submitted with the application should provide as much certainty as possible and be prepared specifically with the aim of enabling the decision-maker to reach a sound and lawful determination of the application' (Clause 6.3.1)

In addition:
- Clause 7.3 of BS42020 (BSI, 2013) states that 'where an applicant has been advised during pre-application discussions, or have themselves identified that they need to provide information on biodiversity with their planning application, they should ensure that what is submitted is sufficient to enable the decision-maker to validate and register the application'. Preliminary ecological appraisal reports (see Chapter 4) are inadequate to inform the planning process unless no further surveys or mitigation are required.
- The 'Note' with Clause 7.3 of BS42020 (BSI, 2013) states that 'failure to provide all the information required might mean an application is not 'valid' and is not considered or determined'. Therefore, good practice would be for an LPA to include biodiversity in its list of local validation requirements and not to validate an application if bat surveys are required (i.e. if there is a reasonable likelihood that bats could be impacted) but none have been carried out.

Information is also available using the online Bat Planning Protocol.[13]

The planning system should also deliver overall net gains for biodiversity (enhancements), as laid out in the National Planning Policy Framework and other planning policy documents.

**1.2.3.1 British Standard for Biodiversity – BS42020:2013**
The Code of practice for planning and development set out within BS42020 (BSI, 2013) provides recommendations and guidance for those in the planning, development and land use sectors whose work might affect or have implications for the conservation or enhancement of biodiversity. It aims to:
- promote transparency and consistency in the quality and appropriateness of ecological information submitted with planning applications and applications for other regulatory approvals;
- give planning authorities and other regulatory bodies greater confidence in the information when they consider proposals for development or land management that potentially affects biodiversity;
- encourage proportionality and a good environmental legacy following development.

Further detail can be found on the British Standards Institution website.[14]

[12] https://www.gov.uk/protected-species-and-sites-how-to-review-planning-proposals
[13] http://www.biodiversityplanningtoolkit.com/bats/bio_bats.html
[14] http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030258704

### 1.2.3.2 Planning trigger list

The planning trigger list in Box 1 presents common development situations where bats are likely to be encountered and therefore where it is most likely that a bat survey will need to be undertaken. **The trigger list is a guide, but it is by no means exhaustive, and professional judgement along with local knowledge should be used to assess where bat surveys are, or are not, appropriate.** Other sites, not listed here, may require a bat survey due to their context, proximity to existing records of bats, the nature of the structure or the proposed activities. Alternative habitats that may initially appear poor for roosting, commuting or foraging bats may be important at particular times of year or in particular situations, for example where other options for bats are limited.

**Box 1 Development and planning trigger list for bat surveys, which can be adapted to local circumstances (taken from the Association for Local Government Ecologists (ALGE) template for biodiversity and geological conservation validation checklists 2007, available from http://alge.org.uk/publications/index.php).**

**(1) Conversion, modification, demolition or removal of buildings (including hotels, schools, hospitals, churches, commercial premises and derelict buildings) which are:**

- agricultural buildings (e.g. farmhouses, barns and outbuildings) of traditional brick or stone construction and/or with exposed wooden beams;
- buildings with weather boarding and/or hanging tiles that are within 200m of woodland and/or water;
- pre-1960 detached buildings and structures within 200m of woodland and/or water;
- pre-1914 buildings within 400m of woodland and/or water;
- pre-1914 buildings with gable ends or slate roofs, regardless of location;
- located within, or immediately adjacent to woodland and/or immediately adjacent to water;
- Dutch barns or livestock buildings with a single skin roof and board-and-gap or Yorkshire boarding if, following a preliminary roost assessment, the site appears to be particularly suited to bats.

**(2) Development affecting built structures:**

- tunnels, mines, kilns, ice-houses, adits, military fortifications, air-raid shelters, cellars and similar underground ducts and structures; unused industrial chimneys that are unlined and brick/stone construction;
- bridge structures, aqueducts and viaducts (especially over water and wet ground).

**(3) Floodlighting of:**

- churches and listed buildings, green space (e.g. sports pitches) within 50m of woodland, water, field hedgerows or lines of trees with connectivity to woodland or water;
- any building meeting the criteria listed in (1) above.

**(4) Felling, removal or lopping of:**

- woodland;
- field hedgerows and/or lines of trees with connectivity to woodland or water bodies;
- old and veteran trees that are more than 100 years old;
- mature trees with obvious holes, cracks or cavities, or that are covered with mature ivy (including large dead trees).

**(5) Proposals affecting water bodies:**

- in or within 200m of rivers, streams, canals, lakes, reed beds or other aquatic habitats.

**(6) Proposals located in or immediately adjacent to:**

- quarries or gravel pits;
- natural cliff faces and rock outcrops with crevices or caves and swallets.

**(7) Proposals for wind farm developments of multiple wind turbines and single wind turbines (depending on the size and location) (NE TIN 051 – undergoing updates at the time of writing).**

**(8) All proposals in sites where bats are known to be present[1]**

This may include proposed development affecting any type of buildings, structures, feature or location.

**Notes:**

1. Where sites are of international importance to bats, they may be designated as SACs. Developers of large sites 5–10km away from such SACs may be required to undertake a HRA.

Chapter 2

# Considerations for bat surveys

## 2.1 Assessing the need for a bat survey

It is reasonable to request surveys where proposed activities are likely to negatively impact bats and their habitats. However, surveys should always be tailored to the predicted, specific impacts of the proposed activities (see Section 2.2.2). Excessive, speculative surveys are expensive and cause reputational damage to the ecological profession.

Bat surveys may be triggered by a client who wants to purchase land, is in the early stages of designing a project or wants to put in a planning application. Alternatively, a bat survey may be triggered by a LPA that has been advised by an ecologist or used a trigger list or biodiversity checklist (see Section 1.2.3.2) to identify the need for one. Bat surveys may be needed to inform an EPS licence application or a Method Statement to facilitate work being carried out without the need for such a licence. Finally, a bat survey may be triggered after a screening exercise has identified the need for an Environmental Impact Assessment (EIA) or an EIA scoping exercise has identified the need for bat surveys.

## 2.2 Elements that influence survey design

### 2.2.1 Stage of proposals

**It is good practice for clients to engage with an ecologist as early as possible when planning a project so that ecology can be factored into the design, timetable and budget at an early stage. Later engagement can result in late design changes and extra delays and costs.**

In addition to the client engaging with an ecologist, early engagement with the LPA and the relevant licensing authority is also beneficial. These two bodies have different functions and may take different decisions on the same proposal. In addition, the granting of, or lack of need for, planning permission does not negate the need to consider protected species legislation.

It is necessary to know what stage the project is at in order to design surveys according to the amount of detail that is required, for example a client considering the purchase of land is likely to require less detail than is required for an EPS licence application and surveys will need to be tailored accordingly.

Large projects such as road schemes or power stations often commence years before any work is carried out on the ground and so surveys in the early years of the project may be at a broad level to identify features of high conservation value to inform project design, with more detail gained later on. It may also be necessary to repeat surveys on projects with long lifespans so that survey data remains current (see Section 2.6.3 for considerations with respect to age of survey data).

### 2.2.2 Potential impacts

The purpose of professional surveys is generally to carry out an assessment of the impacts likely to arise from proposed activities. An ecologist should be provided with (or request) enough information about a project from the start to identify the likely ecological impacts (or lack of impacts) from an early stage. These should be reviewed throughout the project, particularly on larger projects where the proposals may be subject to change over time.

Some impacts on bats and their habitats that can arise from proposed activities are given in Table 2.1.

**Table 2.1 Impacts on bats that can arise from proposed activities**

| Impacts on... ...bats | ...roosting habitats | ...commuting and foraging habitats |
|---|---|---|
| Physical disturbance<br><br>Noise disturbance through, for example, increased human presence or use of noise-generating equipment<br><br>Lighting disturbance<br><br>Injury/mortality (e.g. in roost during destruction or through collision with road/rail traffic) | Modification of access point to roost either physically or through, for example, lighting or removal of vegetation<br><br>Modification of roost either physically, for example by roof removal, or through, for example, changed temperature, humidity, ventilation or lighting regime<br><br>Loss of roost | Modification of commuting or foraging habitats either physically or through disturbance, e.g. light spill/noise<br><br>Severance of commuting routes (fragmentation)<br><br>Loss of foraging habitats |

Different parameters to consider when assessing the different impacts of a project are:

- Is it a positive or a negative impact?
- What is the extent of the impact? What area does it cover?
- What is the magnitude or size of the impact?
- What is the duration of the impact? How long will it last?
- What is the timing and frequency of the impact?
- Is the impact reversible? Will it be temporary or permanent?
- How do the impacts differ throughout the process from pre-construction through construction to operation (and dismantling and restoration for some projects).

More information can be found in *Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal* (CIEEM, 2016).

**The unique combination of project and site will influence the type and nature of potential impacts that are relevant to different projects. Understanding how these elements work together is the key to good survey design.**

### 2.2.3 Zone of influence and defining the survey area

A client should provide a plan showing the site boundary (or red-line boundary for planning purposes), which indicates the area within which proposed activities will take place. Predicted impacts within this boundary will influence the spatial design of surveys. Other considerations when defining survey area are given below.

- The 'zone of influence' of the proposed activities may be different from the site boundary. The term zone of influence (ZoI) is used in formal EIA projects (although the principle can be applied to any project) and is defined by CIEEM (2016) as 'the areas/resources that may be affected by the biophysical changes caused by activities associated with a project'.
- The client's land ownership (the blue line boundary for planning purposes) will determine where access for surveys may be easily obtained.

**All ecologists working on the project should understand how the survey area has been defined and the definition should be revisited as the project evolves.** It is essential for an ecologist to be familiar with up-to-date plans and review the surveys that have been, and will be, carried out accordingly.

### 2.2.4 Defining aims and objectives

It is important at the start of any survey that the **aims and objectives are clearly defined and that the survey report subsequently demonstrates how these have been met.**

The aims of surveying at a proposed development site are generally to:

- collect robust data following good practice guidelines to allow an assessment of the potential impacts of the proposed development on bat populations both on and off site;
- facilitate the design of mitigation, enhancement and monitoring strategies for bats;
- provide baseline information with which the results of post-construction monitoring can be compared, where appropriate;
- provide clear information to enable the LPA and licensing authority to reach a robust decision with definitive required outcomes;
- assist clients in meeting their statutory obligations; and
- facilitate the conservation of bat populations.

Early objectives in a project may be to:

- establish what stage the project is at and therefore what action is needed;
- define the survey area; and
- carry out a preliminary ecological appraisal for bats (Chapter 4) or preliminary roost assessment (Chapters 5 and 6) to inform the design of subsequent, more detailed surveys.

Later objectives may be to:

- obtain roost count data during one active period; and
- trap bats to identify to species level and gain information on gender and breeding status.

Aims and objectives should be revisited throughout a project because each stage of surveying informs the next; bat surveys are an iterative process, which should not usually be fixed from the outset.

### 2.2.5 Proportionality

When planning surveys **it is important to take a proportionate approach**. The type of survey (or suite of surveys) undertaken and the amount of effort expended should be proportionate to the predicted impacts of the proposed activities on bats. Clause 4.1.2 of BS42020 (BSI, 2013) states that 'professionals should take a proportionate approach to ensure that the provision of information with the (planning) application is appropriate to the environmental risk associated with the development and its location'.

Below are other elements that influence the type of survey and effort expended, the examples given being descriptive rather than prescriptive:

- Likelihood of bats being present (e.g. it is often harder and thus may require more survey effort to show that bats are, on the balance of probability, absent from structures rather than present. However, once presence has been established, further surveys may be required to characterise the roost).
- Type of proposed activities (e.g. targeted survey effort may be required for project types known to have specific impacts such as a road scheme or wind farm).
- Scale of proposed activities.
- Size, nature and complexity of the site.
- Species concerned (e.g. some species are harder to detect using standard techniques (such as Bechstein's bat) or are of particular conservation importance (e.g. Annex II species). Different survey types and more survey effort may be necessary if the site is within the range of such species and habitats on site are suitable for the species).
- Numbers of individuals (e.g. sites with larger numbers of individuals (maternity or hibernation roosts or key commuting routes and foraging areas) may require more survey effort to establish numbers or species assemblages).

### 2.2.6 Considering data analysis

Where large amounts of bat activity data are collected using static/automated bat detectors (see Section 8.2) or radiotelemetry is used (see Section 9.3), statistical analysis is important because the meaning is not readily understood just by looking at the data. In particular, trapping and radiotelemetry surveys are highly intrusive and can have implications for bat welfare so a clear plan of why the data is needed, what data is to be collected and how the data will be analysed is essential. If the methods of analysis (see Sections 10.3 and 10.4) are chosen at the survey design stage, this ensures that such testing is possible and makes testing much easier. Data analysis should be an integral part of such surveys and if data collection and analysis are not standard then consideration should be given to conducting a pilot survey.

It is essential that data collected for direct comparison has been collected in the same way, and ideally by the same equipment (e.g. bat detectors, which should be subject to regular testing and calibration); and in suitable conditions, otherwise these factors can introduce bias – differences detected may relate to these factors rather than to real differences on the ground.

In addition, the term 'bat pass' could have a different definition according to equipment and operator, therefore it is important to be clear on how 'bat pass' will be defined when setting out. Some ecologists use 'bat pulse' as the unit of bat activity (rather than bat pass) when analysing their data (see Sowler and Middleton, 2013). The important point is to be consistent.

The main message is that there are various elements that can add bias to survey results and this bias should be minimised as far as is practical.

### 2.2.7 Mitigation hierarchy

The mitigation hierarchy dictates that **impacts should be avoided in the first instance but, where impacts cannot be avoided, then they should be adequately mitigated or, as a last resort, compensated for** (refer to National Planning Policy Guidance para 118, DCLG, 2012). Where mitigation is referred to in these guidelines it should be taken to mean all the elements of the mitigation hierarchy. Definitions of these terms are provided in the *Bat Mitigation Guidelines* (Mitchell-Jones, 2004) and reproduced below.

Mitigation: in this strict sense, mitigation refers to practices which reduce or remove damage (e.g. by changing the layout of a scheme, or altering the timing of the work).

Compensation: this refers to works which offset the damage caused by activities (e.g. by the creation of new roosts).

Following the preliminary ecological appraisal (see Chapter 4) or preliminary roost assessment (see Chapters 5 and 6) it may be possible to identify potential impacts and adjust the design or timing of the project to avoid them. The extent to which impacts can be avoided will influence the design of further surveys. In some circumstances, further surveys may not be needed, in others it may be necessary to collect baseline information against which to compare monitoring data to assess whether impact avoidance has been successfully implemented.

Where negative impacts cannot be avoided through design ('embedded mitigation'), it is reasonable to recommend further bat surveys to facilitate an impact assessment and design a mitigation and monitoring strategy.

### 2.2.8 Using good practice guidance

BS42020 (BSI, 2013) states, in relation to reports submitted with planning applications (although the same principles apply to reports produced as part of an EPS licence application or for other purposes):

> Methods used to undertake surveys and to prepare information presented in ecological reports should (except in the circumstances described below) follow published good practice guidelines where they exist. Claims of compliance with good practice should be substantiated (Clause 6.3.6).
>
> A competent ecologist should, as appropriate, modify their approach from that of published good practice or standing advice issued by a statutory body where, for example:
> (a) it is necessary to adapt to the specific requirements of a case or site;
> (b) an innovative approach might improve upon published good practice and/or provide a more valuable outcome;
> (c) it might only be appropriate to follow good practice guidance in part as the guidance offers a range of optional methods (e.g. for surveys), of which only one is appropriate to the study in question; or
> (d) published good practice is out of date and/or where better techniques have been developed and recognised throughout the profession (Clause 6.3.7).

## 2.3 Bat surveys for development

Figure 2.1 illustrates the process that ecologists should go through when carrying out professional bat survey work where activities are proposed that could impact bats.

**Figure 2.1 The process of carrying out professional bat surveys for proposed activities that could impact bats.**

## 2.4 Survey timing

Bats use different roosts, commuting routes and foraging areas throughout the year according to their life cycle (see Section 3.2) and the availability of their insect prey, which are both influenced by the ambient conditions (temperature, humidity, rainfall, wind) at the location in question. Multiple surveys are usually needed to investigate temporal or seasonal changes in activity; readers should refer to the individual survey chapters (Chapters 4 to 9) for more information. For landscape-scale or higher-impact projects, it is often appropriate to collect data for at least a year.

Table 2.2 provides optimal timings for all types of survey described in these guidelines, although individual survey chapters (Chapters 4 to 9) provide further clarification/caveats with respect to timings. **An experienced surveyor should carry out surveys at a time that gives them the highest chance of establishing whether or not bats are present and how they are using the habitat (including roosts). Actual timings will depend on a number of factors including the surveyor's knowledge and experience of the site and surrounding habitats, existing data records, possible bat species present, geographical location, weather conditions in that particular year and, of course, the aims and objectives of the survey.**

**Table 2.2 Recommended UK survey times for survey types described in these guidelines.**

| Survey type | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D |
| Preliminary ecological appraisal - fieldwork | O | O | O | O | O | O | O | O | O | O | O | O |
| Preliminary roost assessment – structures[a] | O | O | O | O | O | O | O | O | O | O | O | O |
| Emergence/re-entry survey for maternity or summer roosts[b] | | | | | O | O | O | O | | | | |
| Emergence/re-entry[c] survey for transitional roosts[b] | | | | W | | | | | W | W | | |
| Emergence survey for mating roosts[b] | | | | | | | | O | W | W | | |
| Hibernation survey – structures[a] | O | O | W | | | | | | | | W | O |
| Preliminary ground level roost assessment - trees[d] | O | O | O | | | | | | | | | O |
| Potential roost feature (PRF) inspection survey - trees | O | O | O | O | O | O | O | O | O | O | O | O |
| Ground level bat activity survey – transects and automated/static | | | | W | O | O | O | O | W | W | | |
| Pre-, during and post-hibernation – automated/static bat activity survey | W | W | W | | | | | | | | W | W |
| Swarming survey | | | | | | | | O (2nd half) | O | O | | |
| Back-tracking survey | | | | W | O | O | O | O | W | W | | |
| Trapping survey[e] | | | | | O | | O (2nd half) | O | W | W | | |
| Radio tagging and tracking survey[e] | | | | | O | | O (2nd half) | O | W | W | | |

O = optimal period    = sub-optimal period

W = weather or location dependent (i.e. may not be suitable due to spring and autumn conditions in any one year or in more northerly latitudes). Note that October surveys are not acceptable in Scotland.

[a] Not including trees

[b] Please see: Table 7.1 (page 51) for recommended timings for surveys to give confidence in a negative result. For sites assessed as having low suitability a survey should be carried out between May and August. For sites with moderate and high suitability a proportion of the surveys should be carried out between May and August (to detect maternity roosts if present) but some of the surveys may be carried out later in the year in order to detect transitional and mating roosts. The survey season for presence/absence surveys is defined as May to September. Roost characterisation surveys may be appropriate in April and/or October depending on the need to characterise transitional roosts at these times.

[c] The use of dawn surveys in autumn should be clearly justified because longer nights and poorer weather conditions may result in bats returning to roosts early and not re-emerging for pre-dawn foraging, producing a false negative survey result.

[d] Tree surveys can be sub-optimal in the spring, summer and autumn due to foliage obscuring parts of the tree. If all parts of the tree are visible then the survey can be carried out at any time. If parts of the tree are obscured by foliage then it is not possible to carry out a thorough survey and this limitation should be recognised and the impact on the results acknowledged. Please refer to Chapter 6 for more information.

[e] Trapping and tagging surveys should avoid the time when bats are heavily pregnant or lactating unless a project specific licence allows such activities, based on the information needs of the project. Please refer to Chapter 9 for more information.

## 2.5 Resources for surveys

### 2.5.1 Human resources

It is important for those commissioning, scheduling, undertaking and assessing bat survey work to ensure that the ecologists carrying out the work have sufficient training, skills, experience and licences. There is a multitude of bat survey types and the equipment required to carry them out is technical and varied. **None of these surveys can be carried out effectively without specific training and some work also requires ecologists to hold licences to carry out the work legally** (see Section 1.2.2). Alongside survey skills, ecologists planning surveys, leading survey teams, carrying out impact assessments and designing mitigation, enhancement and monitoring schemes require a whole suite of other knowledge and expertise. It is the responsibility of the ecologist and their employer to ensure that appropriate training, skills, experience and licences are in place before carrying out a survey.

Clauses 4.4.1 and 4.3.2 of BS42020 (BSI, 2013) state that 'development proposals that are likely to affect biodiversity should be informed by expert advice' and that ecologists 'should only attempt to offer a bone fide ecological opinion if they have the necessary knowledge, skills and experience to do so, or have secured appropriate competent assistance' respectively.

Clause 4.3.4 of BS42020 (BSI, 2013) states that 'evidence of qualifications, additional training and experience should always be available on request as further evidence of an individual's competence in a particular field of knowledge or area of expertise'.

Training and experience can be gained through mentoring by an experienced and licensed ecologist or attending training courses run by organisations such as the BCT, the Chartered Institute of Ecology and Environmental Management (CIEEM) or other private providers. Local bat groups (LBGs) can also provide training, although this is generally aimed at those carrying out voluntary bat work, for which the aims of surveys are likely to be different. Although skills such as handling and bat identification remain the same for both types of surveys, additional knowledge, skills and experience (such as the ability to design surveys, lead survey teams, assess impacts and design mitigation, enhancement and monitoring strategies) are required to carry out bat surveys professionally.

The BCT published *Professional Training Standards for Ecological Consultants* in 2012. This describes the knowledge and skills required to competently undertake professional bat work to three experience levels, which are described below.

- Level One: To independently and competently undertake professional surveys involving bats.
- Level Two: In addition to the above, to independently and competently lead survey teams/design surveys, assess impacts and design mitigation.
- Level Three: In addition to the above, to independently and competently undertake advanced survey techniques (e.g. trapping and attaching radio transmitters).

The professional training standards document (Bat Conservation Trust, 2012) describes the knowledge and understanding/skill and experience requirements for different topic areas (e.g. Unit 1 Foundation knowledge, Unit 2 Legislation, licensing and planning, Unit 3 Preparation and planning of surveys) in relation to the levels described above and provides performance criteria against which these can be assessed.

CIEEM published *Competencies for Species Survey: Bats* in 2013 (CIEEM, 2013a) in association with BCT, which also describes knowledge, skills and experience required to carry out professional bat work.

While membership of a professional body such as CIEEM (or Chartered Ecologist or Environmentalist status) does not provide evidence for a skill level with respect to bats or other species, members are required to conform to a Code of Professional Conduct. CIEEM's Code of Professional Conduct states that members will:

(i) maintain and develop their professional knowledge and skills and work normally within their sphere of competence; and
(ii) seek advice and assistance if they are involved in topics outwith their sphere of competence (CIEEM, 2013b).

The CIEEM website hosts a professional directory of members,[15] which can be searched according to the services provided.

### 2.5.2 Equipment, documentation and data recording

**The documentation/equipment chosen for a survey should make the survey safer, easier and more efficient, thorough and accurate.** Requirements for documentation/equipment depend on the nature of the survey, the nature of the site and factors such as the client/owner's health and safety requirements. Lists of equipment relevant to different survey types are provided in Appendix 1. A generic list of both documentation and equipment appropriate to all field surveys for bats is provided below:

- any documents that are necessary to allow approved access to the site;
- risk assessment (and biosecurity risk assessment as appropriate);
- any other health and safety documentation;
- copies of relevant licences for the survey activities;
- maps/aerial photographs of the site and surrounding area;
- maps/plans/drawings of site features, clearly illustrating the site boundary;
- any previous survey or background information;
- survey form or digital equipment suitable for recording such as a smartphone, tablet or GPS recorder;
- digital camera;
- spare batteries, bulbs and memory cards for all equipment;
- personal protective equipment (PPE, for example steel toe-capped boots, hard hat, overalls, high visibility jacket, gloves, dust mask);
- first aid kit; and
- charged mobile phone (ensure there is network availability at the site in question and ensure back-up such as hand-held radios or buddy system if no signal).

[15] http://www.cieem.net/members-directory

Where it is necessary to use technical measuring devices (e.g. a thermometer) or recording equipment (e.g. a bat detector), it is essential that the equipment is both calibrated and tested on a regular basis to ensure that when the results are compared this is a like-for-like comparison. Similarly, it is essential to have a good understanding of the settings and the sampling rate of detectors. Different bat detector microphones vary in their sensitivity (Adams *et al.*, 2012) and this should be considered. The benefit of recording bat activity is that there is an auditable record of work carried out; data should be retained for this purpose.

Data recorded during a survey should be accurate, thorough and consistent across surveys of the same type. Standard survey forms should be used for each survey type to prompt the ecologist to record all the information necessary (and no more) and allow the raw data to be passed on if the need arises, such as in a public inquiry.

When recording survey results, it is obviously important to record positive sightings but it is also important to make a record where a site or feature has been surveyed but returned a negative survey result (i.e. not suitable for bats or no evidence of bats found). This information can be just as important when justifying subsequent actions undertaken.

## 2.6 Dealing with survey limitations

Clause 6.7.1 of BS42020 (BSI, 2013) states that 'To reduce uncertainty, and to achieve full scientific disclosure, those undertaking surveys and preparing ecological advice and reports should identify all relevant limitations' with respect to methods and site conditions. Clause 6.7.2 of BS42020 (BSI, 2013) states that 'any limitations associated with work should be stated, with an explanation of their significance and any attempt made to overcome them. The consequences of any such limitations on the soundness of the main findings and recommendations in the report should be made clear.'

### 2.6.1 Weather conditions

The weather affects bat activity and therefore surveyors should check weather forecasts prior to surveys for active bats and record weather conditions, **including temperature, wind speed and precipitation**. These variables should be recorded at the start and end of each survey and if conditions change during the survey. When ecologists are not present (for example, during automated/static monitoring surveys) options for recording weather conditions include a temperature logger, a weather recording station and obtaining meteorology data online. This data provides context to the survey results and therefore a plan should be in place to ensure it is recorded/obtained.

Additionally, the weather conditions prior to the survey may influence bat activity (e.g. a dry spell after a long period of rain may result in bats foraging for longer because they are hungry) and could be recorded and reported if this is the case.

The effect of weather conditions on active bats is likely to be different for different species (with different flight capabilities) in different situations (for example, open versus sheltered habitats).[16]

The aim should be to carry out surveys in conditions that are close to optimal (sunset temperature 10°C or above, no rain or strong wind), particularly where only one survey is planned. Where multiple surveys are planned, carrying them all out in optimal conditions enables a like-for-like comparison of results, although it is recognised that in spring and autumn, and particularly in more northerly latitudes, these conditions may be rarer and some of the surveys may need to be carried out at lower temperatures or in more windy conditions. This situation does provide some insight into how the bats respond to poorer conditions. Surveys carried out when the temperature at sunset is below 10°C should be justified by the ecologist and the effect on bat behaviour considered. In cooler, wetter and windier conditions bats may not emerge, emerge later, forage for shorter time periods, carry out fewer foraging bouts or use alternative, more sheltered habitats.

### 2.6.2 Restricted access

Clients may have specific requirements for access to sites such as items of PPE, documentation or that surveyors are escorted by site personnel. Some sites may require specialist equipment; for example, gas monitors in a confined space. Site-specific requirements should be established before the site visit and should not be cited as limitations to a survey if they can be met through advance planning.

Sometimes it is not possible to gain permission to access land. In this situation, it is recommended that a record of access requests and any responses received are retained as evidence that access permission was sought but was not granted.

Access to survey may also be restricted for health and safety reasons; for example, a building may be structurally unsound or a tree may not be safe to climb. Documentation may be available from a structural engineer or arboriculturist as evidence but, if not, justification should be provided in the bat survey report). In situations where a thorough preliminary ground level roost assessment or PRF inspection survey is not possible, the number of presence/absence surveys may need to be increased accordingly.

The impact of any remaining limitations (relating to access) on the resulting data should be acknowledged in the report.

### 2.6.3 Age of survey data

Ideally, the survey data should be from the last survey season before a planning or licence application is submitted, although often data older than this can have considerable value, particularly where collected over a number of years using different techniques. The value of older data should be considered when updating surveys as it may not be necessary to start from scratch.

[16] Kronwitter (1988) studied the influence of temperature and precipitation on the activity of noctule bats in Germany, observing no emergence, late emergence and fewer foraging bouts in cooler conditions and later emergence in rainy conditions. Slack and Tinsley (2015) looked at bat activity at wind farm sites and found no bat activity at temperatures below 6°C, limited bat activity below 10°C and a reduction in bat activity at wind speeds of 5.4m/s and greater. Radio-tagged barbastelle bats exhibited the same behaviour in wind speeds of 11m/s as on previous calmer nights in a study by Davidson-Watts (2014a).

In some cases, data may be needed from the night before operations are carried out either to confirm that bats have left an identified roost, or as a precautionary measure.

**The length of time survey data remains valid should be decided on a case-by-case basis and is dependent on a number of questions**, as follows:

- Were the original surveys carried out according to good practice guidelines?
- Were the original surveys constrained in any way (in terms of timings, weather conditions, equipment used, number of surveyors, surveyor expertise, etc.)?
- Do the results of the original surveys support the original conclusions and are these still relevant?
- Has the nature of the site or the surrounding area changed since the original surveys (e.g. has a structure deteriorated and become less suitable for a roost or has human occupation ceased and the structure become more suitable for a roost)?
- Are additional surveys likely to provide information that is material to a decision (such as a planning consent), the design of mitigation measures, or specific advice relating to a proposed activity?

### 2.6.4 Other potential limitations

The availability or cost of equipment should not be cited as a reason for not using the most appropriate piece of equipment for a bat survey. Professional ecologists should ensure that they consult with the client to establish the nature of the site and scrutinise bat records and previous survey results to ensure they have the right equipment to carry out their work.

Some equipment is inherently constrained but still the most appropriate equipment for the job; for example, bat detectors can only provide an index of activity rather than absolute numbers of bats (see Section 10.2) and some species are difficult to detect due to their quiet echolocation calls (see Section 3.9). These constraints should be acknowledged in the report and methods to overcome them described.

Bat surveys are seasonally constrained and this should be factored into project scheduling to ensure that surveys are carried out at the most appropriate time of year. Ideally, timing should not be cited as a limitation to the survey.

## 2.7 Health and safety

**It is the legal duty of an employer to have a written health and safety policy unless they employ fewer than five employees (although even in this situation it is good practice to have a policy in place). Guidance on safety and risk management can be found on the HSE's website.**[17]

A hazard is something that has the potential to cause harm; it is associated with a degree of danger and is quantifiable in terms of its severity. Risk is the actual likelihood of harm from a particular hazard. If a risk is considered too high then the proposed action should not be undertaken or measures should be applied to either remove the hazard or avoid/reduce the risk that the hazard poses. It is generally more appropriate for bat surveys to be undertaken in pairs or within a larger team due to the potential risks involved. However, it may be possible to adequately control the risks to a lone worker in certain circumstances.

Bat surveys have some very specific risks arising from particular hazards such as working at height, confined spaces, asbestos and night-time working resulting in tiredness. It is important that these hazards are adequately considered and risks are adequately controlled before surveys are undertaken. The most effective way to ensure this is by carrying out a risk assessment. A targeted risk assessment should be prepared and completed for every site, to ensure that any site-specific risks are considered alongside generic risks. On arrival on site, for every visit, the risk assessment should be reviewed to establish that all possible risks have been taken into account. There should be a mechanism in place for items to be added to the risk assessment and for this information to be available for subsequent site visits (particularly important if different staff are deployed each time).

Appendix 3 lists hazards and risks associated with bat fieldwork and measures that can be taken or equipment that can be used to manage them. Sample risk assessments and guidance on completing them can be found on the HSE website.[18] Guidance on carrying out risk assessments for lone working is also available from the Member's Area of the CIEEM website.[19] General guidance on health and safety is also provided in CIEEM's *Good Working Practices* (CIEEM, 2013c).

In some situations, particularly for larger developments, the site owner/developer/client will also have their own risk assessment, a health and safety induction and/or other related procedures.

All equipment used should be regularly checked and maintained, in line with appropriate legislation (this may require formal inspections by accredited bodies).

The following types of work require advanced knowledge and the use of specialist equipment; information can be gained on the specialist training courses indicated.

- Work in confined spaces (tunnels, culverts, etc.) – confined spaces training course.
- Working at height – working at height training courses provide training on the safe use of ladders and assessment of which equipment is appropriate to the task.
- Work in trees – arboricultural climbing course provides training in the use of specialist equipment and climbing/aerial rescue techniques.
- Work underground (mines, caves, etc.) – confined spaces training course, mine safety course. Basic caver training and advice on safety issues in specific local caves and mines can also be obtained from the British Caving Association (BCA), Regional Caving Councils or local caving clubs.
- Work on a construction site – to get an Ecologist CSCS (Construction Site Certification Scheme) card, you need to apply for the card through the BALI (British Association of

[17] http://www.hse.gov.uk/pubns/indg449.pdf
[18] http://www.hse.gov.uk
[19] http://www.cieem.net

Landscape Industries) website.[20] Before you can apply you need to attend a 1 day ROLO H&S training day and sit the touch screen test.

- Work in buildings which may contain asbestos – asbestos awareness training course. Asbestos may be present in structures built before 2000; some such buildings may have an asbestos risk register that can be requested and scrutinised prior to entry.

Whether employers provide vehicles or expect employees to drive their own for work purposes, they should have a policy to address working hours, time spent driving and vehicle maintenance. The Health and Safety Executive (HSE) estimates that up to a third of all road traffic accidents involve a driver who is at work at the time. Road accidents are a particular risk for ecologists carrying out nocturnal bat surveys, as the functionality of a driver decreases with increasing sleep deprivation or fatigue. Companies therefore have a duty to develop policies to ensure safe working practices, and it is recommended that driving is included in working hours in these policies.

Where phone reception is poor it may be necessary to use 112 in an emergency.[21]

## 2.8 Insurance

Before undertaking any work for a client, ecologists should have appropriate insurance, including professional indemnity insurance and public liability insurance. For members of CIEEM, adequate insurance cover is a strict requirement of membership.

Professional indemnity insurance can help protect an ecologist if claims are brought against him or her by a client, due to a perceived problem with the work undertaken. Professional indemnity insurance is needed if an ecologist provides advice to a client, handles data belonging to a client, is responsible for a client's intellectual property, or provides professional services, and if an ecologist's work could be challenged or questioned. Ecologists may be vulnerable to claims of negligence if professional advice or services fail to meet a client's expectations or are perceived to cause financial loss.

Public liability insurance covers the compensation an ecologist may have to pay a client, contractor or member of the public, due to accidental injury or property damage caused by the ecologist either on the ecologist's premises, during field surveys or at a client's premises.

## 2.9 Summary

Ecologists should be considering the following questions as they carry out their professional survey work:

- Is there a need for survey work to be carried out?
- Is the purpose of this work understood in relation to the current stage of the project?
- Have the aims and objectives of the work been clearly defined and are these fit for the purpose they were intended?
- Will the stated aims and objectives of the survey work be achieved?
- Is the survey work proportionate to the impacts?
- Have the potential impacts, the ZoI and the impacts that could be avoided through design been adequately assessed?
- Is the defined survey area appropriate?
- Are the most appropriate survey types being used?
- Are the surveys being carried out according to good practice? If not, then how will any limitations be accounted for?
- Do the surveys fit in with the planned project schedule? Do the surveys or schedule need to be amended?
- Does the team have the competence to carry out the survey work?
- Does the team have the capacity to carry out the survey work?
- Has the right equipment been chosen for the survey work? Does the team have the right equipment? Does the equipment need calibrating, testing or servicing?
- Is all of the appropriate data being recorded?
- Are there any specific health and safety requirements that need to be fulfilled and will this impact on the survey results/survey schedule?
- Is site access available to allow the surveys to be carried out efficiently and effectively within the defined survey area?
- Has the project been altered recently such that the surveys or schedule need to be reviewed?
- Has all the relevant information been requested from the client and communicated back?
- Have clear and definitively stated outcomes been provided to enable the LPA to include conditions in a planning decision?
- Have the client's expectations been realistically managed in terms of meeting good practice and being clear on planning and licensing requirements?

[20] http://www.bali.org.uk/quality_assurance/liss_cscs/ occupations#environmental
[21] See https://www.youtube.com/watch?v=XPZv_8dABfU for information on maximising chances of getting hold of the emergency services.

Chapter 3

# Ecological considerations for bat surveys

## 3.1 Introduction

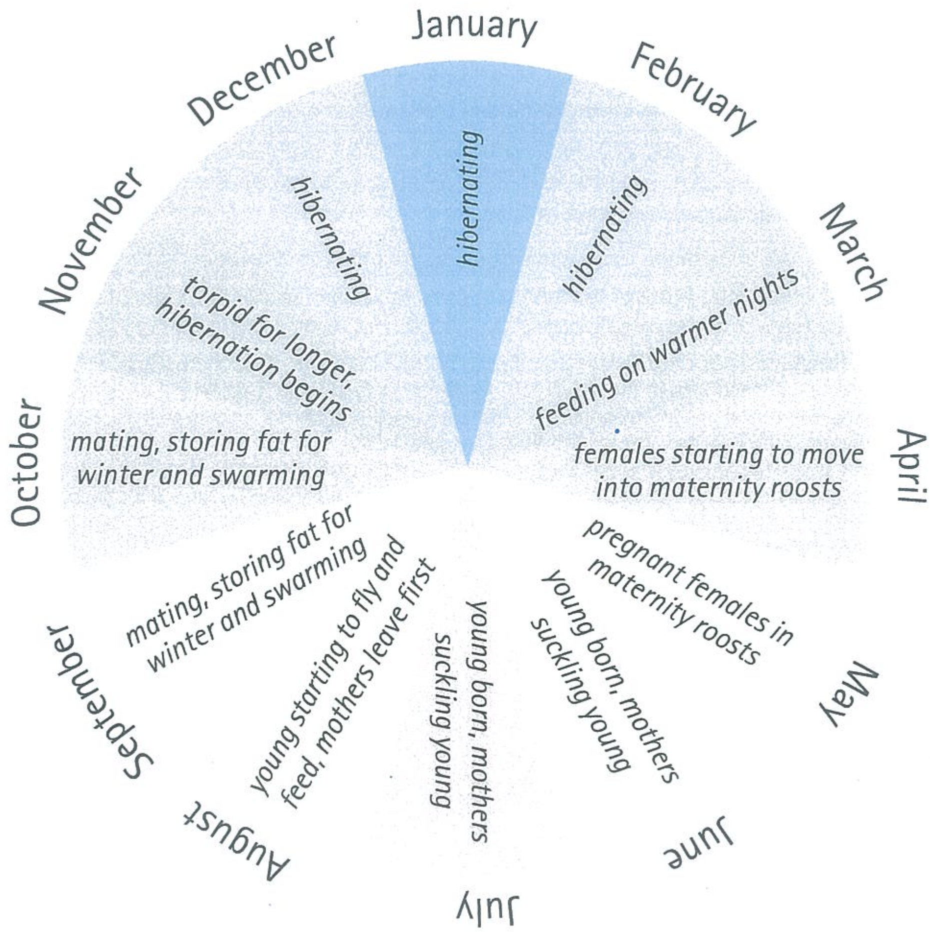
Knowing about the ecology of the different species is necessary to determine how bats are likely to use the landscape, so that appropriate survey methods can be chosen. Bats are cryptic, use large geographical areas in three-dimensional space, and have the potential to disperse over large areas, so that they are difficult to survey without an understanding of their ecology.

Due to the relatively recent discovery of Alcathoe bat (*Myotis alcathoe*), the ecology of this species in the UK is poorly understood and therefore this species is not included in the species tables in the following sections.

## 3.2 Bat life cycle

Figure 3.1 provides a visual representation of the life cycle of a bat; further descriptions are provided in the text below.

**Figure 3.1 Bat life cycle.**




UK bats spend much of the winter (dependent on conditions in any one year at any specific location) in torpor at hibernation sites, although they will rouse on warmer nights to drink, forage and expel waste products. Bats can also change hibernacula depending on weather conditions.

During the spring bats feed more and more during the night and the period from April (likely to be slightly later in northerly latitudes) to early June is a time of intense feeding to recover weight lost during the winter. During this time, females gather together at maternity roosts that provide appropriate conditions to rear young. In some species, males are also present in maternity roosts although for many species the males roost elsewhere either individually or in small groups.

Birthing times can be highly variable between locations, years, species and even between individuals of the same species. However, the main period for births is June, then the young begin to fly in July and August, at first still taking milk from their mothers but gradually becoming more independent (Dietz *et al.*, 2011). As the young become independent, the females disperse to find mates and gain weight before winter.

During autumn, many *Myotis* bats swarm at caves and mines to mate and/or find a hibernation site. Males of some species establish mating territories where they may fly or call specifically to attract females.

As the weather turns colder, bat activity declines and foraging becomes restricted to warmer nights. Bats spend progressively more time in torpor and slowly return to their hibernacula.

## 3.3 Bat roost types

The definitions of different roost types in Table 3.1 have been taken from the NE EPS licence application form available at the time of writing.

**Table 3.1 Bat roost types (from NE EPS licence application form available at the time of writing).[a]**

| Roost type | NE definition |
|---|---|
| Day roost | A place where individual bats, or small groups of males, rest or shelter in the day but are rarely found by night in the summer. |
| Night roost | A place where bats rest or shelter in the night but are rarely found in the day. May be used by a single individual on occasion or it could be used regularly by the whole colony. |
| Feeding roost | A place where individual bats or a few individuals rest or feed during the night but are rarely present by day. |
| Transitional/occasional roost | Used by a few individuals or occasionally small groups for generally short periods of time on waking from hibernation or in the period prior to hibernation. |
| Swarming site[b] | Where large numbers of males and females gather during late summer to autumn. Appear to be important mating sites. |
| Mating sites[c] | Where mating takes place from late summer and can continue through winter. |
| Maternity roost[d] | Where female bats give birth and raise their young to independence. |
| Hibernation roost | Where bats may be found individually or together during winter. They have a constant cool temperature and high humidity. |
| Satellite roost | An alternative roost found in close proximity to the main nursery colony used by a few individual breeding females to small groups of breeding females throughout the breeding season. |

[a] The table defines roost types for the purposes of consistency but it should be noted that not all of these sites are also breeding sites, resting places or places used for shelter or protection as described in the legislation. Judgements as to what is protected under law should be undertaken on a case-by-case basis (the term roost is not used in the legislation). The EU has provided guidance on this point in: Guidance on the strict protection of animal species of community interest (2007). Please also see Sections 1.2.1 and 1.2.2.

[b] Roosting may occur alongside the swarming activity and it is the structures used for rest and shelter within the swarming site that are the roost.

[c] Mating sites can include those where bats call for mates on the wing; however, these are also associated with a place that the mating takes place, which is the mating or harem roost.

[d] In some species, males may also be present in the maternity roost.

## 3.4 Species roosting preferences

Table 3.2 provides information from studies of the roosting preferences of different bat species. It should be noted that this table is not exhaustive and was not derived from a thorough literature search – species may be found to roost in different locations to those described here.

**Table 3.2 Roosting preferences of different species.**

| Species common name | Species scientific name | Roosting preferences |
|---|---|---|
| Greater horseshoe bat | *Rhinolophus ferrumequinum* | During the summer females use large, old, undisturbed buildings (Bat Conservation Trust/BMT Cordah Limited, 2005) including coach houses, stable blocks and barns (Duvergé and Jones, 2003). This species prefers to fly directly into the roost and to their roosting position and bats hang freely (Ransome and Hutson, 2000). Maternity sites are often found in large spaces at least 3-4m high, providing a sufficiently large flight area (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>This species generally uses night roosts to rest whilst foraging, which are found in a variety of structures, for example outbuildings, garages, stables, milking sheds, porches and trees (Duvergé and Jones, 1994; Ransome and Hutson, 2000; Duvergé and Jones, 2003).<br><br>Male bats remain solitary through the summer and often use underground sites (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>In winter, both male and female bats choose underground sites for hibernation, including tunnels, mines, caves or cold building basements (Bat Conservation Trust/BMT Cordah Limited, 2005). Requires a range of conditions in a series of suitable hibernacula (Harris and Yalden, 2008). The main hibernation site is usually within 15km of the maternity roost, but some bats may travel up to 60km between such sites (Ransome and Hutson, 2000).<br><br>Faithful to traditional summer and winter roosts (English Nature, 2003). |
| Lesser horseshoe bat | *Rhinolophus hipposideros* | Roost sites include attics, chimneys and boiler rooms of buildings, rural houses and outbuildings in the summer, and cellars, tunnels, disused mines and caves for hibernation (Schofield *et al.*, 2002). Also found in industrial buildings. This species prefers to fly directly into roost sites and into their roosting position (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>Maternity sites are often found in large roof spaces at least 3-4m high providing a large flight area (Bat Conservation Trust/BMT Cordah Limited, 2005). A range of conditions is required throughout the year but this may be found in one building with, for example, an attic for the summer and a cellar for the winter. Summer and winter roost sites are generally no more than 5-10km apart (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>The lesser horseshoe bat also uses alternative roost sites during the night and day. |
| Daubenton's bat | *Myotis daubentonii* | Roosts are found in hollow trees, bridges or sometimes buildings (Billington and Norman, 1997) generally close to water (Racey *et al.*, 1998). Nursery roosts are not exclusively female (Angell *et al.*, 2013) – males may make up 25% or more of the colony and large male-only colonies have also been recorded. Boonman (2000) found that this species selected oaks over beech trees and preferred roosts on the edges of woodlands in a study in the Netherlands. Hibernation sites are usually underground including caves, mines and suitable tunnels where bats are found both in crevices and on open walls (Altringham, 2003). They may also hibernate in tree cavities (Bat Conservation Trust/BMT Cordah Limited, 2005). |

| Species common name | Species scientific name | Roosting preferences |
|---|---|---|
| Brandt's/whiskered bat[22] | *Myotis brandtii/mystacinus* | Both species can roost in trees and a wide range of buildings in the summer (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>Hibernates in caves or other underground sites, where they can be found in the open or in cracks and crevices (Altringham, 2003). |
| Natterer's bat | *Myotis nattereri* | Roost sites include tree holes and different types of buildings but has also been found in bridges (Billington and Norman, 1997; Smith and Racey, 2002). Usually roost in attics between late May and mid-July (Smith and Racey, 2002) and often roosts have enough space for internal flight (Swift, 1997). This species also breeds in bat boxes (Park *et al.*, 1998; Bilston, 2014).<br><br>Timber-framed barns built between the 12th and 19th centuries may be particularly important to this species (Briggs, 1995, 2002), with roosts found in mortise joints in both the summer and winter.<br><br>Hibernates in cracks and crevices in caves and mines (Altringham 2003). Other hibernation sites recorded are canal and railway tunnels, ice houses and tree cavities (Smith and Racey, 2002). |
| Bechstein's bat | *Myotis bechsteinii* | Maternity roosts are found in tree holes in the canopy, generally in old trees with dead branches (Altringham, 2003). May be found in woodpecker holes in old oaks (Bat Conservation Trust/BMT Cordah Limited, 2005). Recorded switching roosts frequently (Kerth *et al.*, 2001; Reckardt and Kerth, 2007)). One study recorded roosts in rot holes, woodpecker holes and in a gap behind thick ivy (Palmer, 2013). A study of ten colonies across the Isle of Wight found 90% of maternity roosts in woodpecker holes in ash trees (Davidson-Watts, 2008). Another study found a maternity roost in a woodpecker hole in an oak tree on a golf course (Davidson-Watts, 2014b).<br><br>Hibernates in trees and sometimes caves or other underground sites (Harris and Yalden, 2008). Chilmark Quarry is an example of Bechstein's bats using an abandoned mine for hibernation.[23] |
| Noctule | *Nyctalus noctula* | Roosts almost exclusively in tree holes, but sometimes found in bat boxes or buildings (Altringham, 2003). One Netherlands study found that woodpecker holes are preferred, in trees close to woodland edge (Boonman, 2000).<br><br>Hibernates in trees but sometimes found in buildings (Bat Conservation Trust/BMT Cordah Limited, 2005). |
| Leisler's bat | *Nyctalus leisleri* | Roosts in trees, bat boxes and buildings such as houses; for example, around the gable end of lofts, under tiles, under soffit boards and in disused chimneys (Corbet and Harris, 1991). Often uses a variety of sites in the summer (Waters *et al.*, 1999).<br><br>Hibernates in tree holes, buildings and sometimes underground sites (Bat Conservation Trust/BMT Cordah Limited, 2005). |

[22] Brandt's and whiskered bats were only separated in 1971. Their ecologies are apparently similar although further research is needed.
[23] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0016373

| Species common name | Species scientific name | Roosting preferences |
|---|---|---|
| Common pipistrelle and soprano pipistrelle | *Pipistrellus pipistrellus and P. pygmaeus* | Maternity colonies are found mainly in buildings, usually roosting out of sight in crevices. Colonies may use a number of sites through the summer but are often loyal to the same sites for many years (Thompson, 1992). Maternity colonies are extremely variable in terms of numbers, from 20 to over 1,000 bats (Speakman *et al.*, 1999). Barlow and Jones (1999) found that soprano pipistrelle colonies (median of 203) tended to be larger than those of the common pipistrelle (median of 76). Davidson-Watts *et al.* (2006) reported common pipistrelle shifting roosts between pregnancy and lactation. Davidson-Watts (2007) found that roost selection was based on temperature for common pipistrelle and on surrounding habitats (woodland and water) for both species.<br><br>Males roost singly or in small groups in the summer, in buildings or trees (Lundberg and Gerell, 1986). Bat boxes are used by both males and females but generally only males use them during the summer (Park *et al.*, 1998).<br><br>These species do not use underground sites for hibernation but are sometimes found in the cracks and crevices of buildings in the winter (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>Evidence from the Netherlands shows mass swarming events of common pipistrelle bats in the autumn followed by mass hibernation in a diverse range of building types in urban environments (Korsten *et al.*, 2015). This phenomenon requires some research in the UK but ecologists should be aware of the potential for larger numbers of this species to be present during the autumn and winter in large buildings in highly urbanised environments. |
| Nathusius' pipistrelle | *Pipistrellus nathusii* | The very few known British nursery roosts are in buildings, with hibernation roosts in hollow trees and crevices in cliffs, walls and caves (Altringham, 2003). One study recorded males roosting under lead flashing and roof tiles (Hargreaves, 2012). |
| Serotine | *Eptesicus serotinus* | Roosts in buildings in small cavities or crevices with high access points such as gables but occasionally also found in trees (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>Recorded hibernation sites include cavity walls, disused chimneys and occasionally caves (Bat Conservation Trust/BMT Cordah Limited, 2005). |
| Barbastelle | *Barbastella barbastellus* | In summer, breeding females move regularly (Greenaway, 2008) between a large number of different tree roosts (Billington, 2003; Greenaway, 2001; Zeale, 2011). One study found that they preferred dead trees surrounded by holly understorey (Greenaway, 2001) and another found them in tree crevices and cavities, between overlapping limbs and behind ivy, on average 6.9m above ground level (Billington, 2003). Greenaway (2008) found that tree roosts were in relatively undisturbed places and frequently in thick cover, although cracks much higher up in trees were used at the time of birth. Bat boxes are also used (Greenaway, 2008). Davidson-Watts (2008, 2014a) reported almost all roosts found in two studies were behind loose bark and in mixed locations not always surrounded by understorey.<br><br>Winter roosts include deep, hollow trees (usually dead and among holly understorey) and sometimes buildings or underground sites (Greenaway, 2001). Other winter roosts recorded are flaking bark and splits less than 2m above the ground (Billington, 2000) and disused railway tunnels, barns, outbuildings, church porches and lime kilns. Chilmark Quarry is an example of barbastelle bats using an abandoned mine for hibernation.[24]<br><br>Spring and autumn roosts have been recorded behind loose bark (Billington, 2000; Greenaway, 2001), in dead tree stumps (Greenaway, 2001) and in splits in limbs mainly less than 2m above ground level (Billington, 2000). |

[24] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0016373

| Species common name | Species scientific name | Roosting preferences |
|---|---|---|
| Brown long-eared bat | *Plecotus auritus* | Maternity roosts found in trees, in the voids of large, old buildings and bat boxes in woodland (Briggs, 1995; Bilston, 2014). Usually roosts against wooden beams at the roof apex in attics or farm buildings (Bat Conservation Trust/BMT Cordah Limited, 2005). Bats often cluster at the highest part of the roof and require enough space for unobstructed, internal flight (Entwistle *et al.*, 1997). Shows high roost fidelity (Entwistle *et al.*, 1997).<br><br>Commonly uses feeding perches and night roosts in porches or outbuildings separate from the main roost (Bat Conservation Trust/BMT Cordah Limited, 2005).<br><br>Hibernate in underground sites, tree holes and buildings (Bat Conservation Trust/BMT Cordah Limited, 2005). |
| Grey long-eared bat | *Plecotus austriacus* | Frequently roosts on ridge beam in spaces between rafters. Maternity colonies show high roost fidelity (Razgour *et al.*, 2013). Number of males in maternity colony increases through summer. Many males are, however, solitary. |

## 3.5 Species emergence times

Table 3.3 provides information on the emergence times of different bat species. The time of emergence from a roost depends on the species' ecology, the amount of protective cover around the roost, the reproductive status of the bats in question, and the ambient weather conditions on the night in question and on previous nights. For some species, there is a fine balance between the need to forage and vulnerability to predators, and therefore absolute times after sunset have not been provided. Instead, the species have been separated into 'earlier' and 'later' emerging species. It should be noted that species known to exit roosts later may actually exit the roost itself earlier but remain under cover until it gets dark. The behaviour where bats appear to fly back and forth to 'test' light levels before fully emerging is often termed 'light sampling', but its actual function is unknown.

**Table 3.3 Approximate emergence times of different UK species.**

| Earlier emerging species | Later emerging species |
|---|---|
| Noctule | Lesser horseshoe bat |
| Leisler's bat | Greater horseshoe bat |
| Common pipistrelle | Daubenton's bat |
| Soprano pipistrelle | Brandt's bat |
| Nathusius' pipistrelle | Whiskered bat |
| Serotine | Natterer's bat |
| | Bechstein's bat |
| | Barbastelle |
| | Brown long-eared bat |
| | Grey long-eared bat |

## 3.6 Species foraging habitat preferences

Table 3.4 provides information on the foraging habitat preferences of different bat species. As foraging is influenced by the availability and quality of habitat around the roost, the time of year (linked to seasonal prey abundance) and the ambient conditions on the night in question this table should not be considered exhaustive (and was not derived from a thorough literature search). Bats have also been found in open landscapes such as farmland, mires, moorlands and coastal cliffs.

**Table 3.4 Foraging habitat preferences and foraging strategies of different UK species.**

| Species | Foraging habitat preferences (with commuting preferences added for some species) |
|---|---|
| Lesser horseshoe | Preferred foraging habitats include broadleaved woodland well connected by commuting routes such as hedges, woodland edge and riparian trees (Bontadina *et al.*, 2002; Schofield *et al.*, 2002). This species has also been recorded in coniferous woodland (Schofield *et al.*, 2002). Probably reluctant to cross open space as recorded flying very low (less than 1m) in open habitats (Schofield *et al.*, 2002). This species can remain active during the hibernation period (Williams, 2001). |
| Greater horseshoe | Preferred foraging habitats are ancient semi-natural and deciduous woodland and cattle-grazed pastures (Duvergé and Jones, 1994; Ransome, 1997; Duvergé and Jones, 2003). Bats tend to forage on the boundaries of grazed pastures and woodland, tree lines or tall, thick hedgerows (Ransome, 1997). One study showed that bats fly close to field boundaries and reduce their flight height when out in the open (Duvergé and Jones, 2003). A spring study showed grazed pastures and broadleaved woodland were selected over other habitats (Flanders and Jones, 2009). This species can remain active during the hibernation period (Park *et al.*, 1999). |
| Daubenton's bat | Preferred foraging habitat is over water (Jones and Raynor, 1988): this species favours riverine habitats (Racey and Swift, 1985; Rydell *et al.*, 1994) but is also known to forage in woodland. |
| Whiskered / Brandt's bat | Buckley *et al.* (2013) found whiskered bat used mixed woodland, riparian vegetation, arable and rough grassland habitats although selected the first two as core foraging habitats. Berge (2007) found that whiskered bat selected pasture with hedgerows. A German study showed Brandt's bat favours woodland and whiskered bat favours areas near rivers and more open habitats with hedges and coppices (Taake, 1984). |
| Natterer's bat | Preferred foraging habitat is semi-natural broadleaved woodland, tree-lined river corridors and ponds, but also uses grassland (Smith and Racey, 2002, 2008). Avoids dense coniferous plantation (Smith and Racey, 2008). An autumn study revealed the species to use woodland and mixed agricultural areas (Parsons and Jones, 2003). |
| Bechstein's bat | Predominantly associated with ancient broadleaved woodlands (Greenaway and Hill, 2004), with a strong association with oak and ash (Hill and Greenaway, 2005). Various studies have recorded foraging under a closed canopy (Fitzsimons *et al.*, 2002, Harris and Yalden, 2008). One recent study recorded foraging in mixed-age coppice, high forest with little understorey, unimproved grassland, a dry stream corridor with scrub and trees and tree lines and hedgerows in a pastoral landscape (Palmer, 2013). Commuting was recorded along the stream corridor and hedgerows (Palmer, 2013). Davidson-Watts (2014b) also reported use of hedgerows in grazed pasture for commuting and patches of coniferous woodland used for commuting when these were present as part of a larger broadleaved block. Davidson-Watts (2013) also reported use of tree-lined river margins. |
| Noctule | Found in a range of habitats, forages out in the open, often over trees and with a strong affinity to water (Altringham, 2003). Reported as selecting broadleaved woodland and pasture (Mackie and Racey, 2007). |
| Leisler's bat | Recorded foraging in woodland edge, scrub or woodland-lined roads and over pasture (Waters *et al.*, 1999). Also recorded over drainage canals, lakes and coniferous forests (Shiel *et al.*, 1999). Recorded as selecting parkland/amenity grassland, deciduous woodland edge and rivers/canals but avoiding improved grassland (Russ and Montgomery, 2002). One road-based study showed this species to be equally active in all habitats available (hedges, tree lines, woodland, grassland, streetlights and arable areas) (Russ *et al.*, 2003). |
| Common pipistrelle | Shows a preference for deciduous woodland but a generalist using a wide range of habitats (Davidson-Watts and Jones, 2006; Davidson-Watts *et al.*, 2006). |
| Soprano pipistrelle | Tends to select riparian habitats over other habitat types available (Davidson-Watts and Jones, 2006; Davidson-Watts *et al.*, 2006). |

| Species | Foraging habitat preferences (with commuting preferences added for some species) |
|---|---|
| Nathusius' pipistrelle | Riparian habitats, broadleaved and mixed woodland and parkland, occasionally found in farmland but always near water (Harris and Yalden, 2008). Found over lakes and rivers (Vaughan *et al.*, 1997). One study recorded males feeding over lake edge and managed gardens and fields around a lake (Hargreaves, 2012). |
| Serotine | Catto *et al.* (1996) and Robinson and Stebbings (1997) identified the following habitats as important for foraging: cattle pasture, playing fields, village greens, white streetlights, tree-lined hedgerows and woodland edge. |
| Barbastelle | Forages over/in riparian zones, broadleaved woodland, unimproved grassland and field margins (Zeale, 2011; Zeale *et al.*, 2012). Foraging has also been recorded at an irrigation reservoir, ponds in woodland, areas of set-aside, floodplain habitats, a sewage farm and a pumping station (Greenaway, 2008). Bats tend to wait for darkness to cross open areas (Greenaway, 2008). However, barbastelle avoided wetlands, preferring woodlands and treelines in a study by Davidson-Watts (2014a). |
| Brown long-eared | Strongly associated with tree cover (Entwistle *et al.*, 1996), prefers woodland with cluttered understorey including native species, particularly deciduous (Murphy *et al.*, 2012). Also forages in mixed woodland edge and among conifers. Use of hedgerows increases through the active season (Murphy *et al.*, 2012). |
| Grey long-eared | Prefers to forage in more open or edge habitats, including unimproved lowland grassland (meadows and marshes), wooded riparian vegetation and broadleaved woodland (woodland mainly used in low temperatures or heavy rainfall) (Razgour *et al.*, 2011, 2013). In agricultural habitats, forages along field margins, hedgerows and scattered trees. |

## 3.7 Species Core Sustenance Zones

BCT has been working on defining Core Sustenance Zones (CSZs) for different bat species through an extensive literature review (see Table 3.5). A CSZ refers to the area surrounding a communal bat roost within which habitat availability and quality will have a significant influence on the resilience and conservation status of the colony using the roost.

With reference to development, the CSZ could be used to indicate:

- The area surrounding a communal roost within which development work may impact the commuting and foraging habitat of bats using that roost.
- The area within which it may be necessary to ensure no net reduction in the quality and availability of foraging habitat for the colony.

Consideration should be given to the extent of a background data search in relation to the species likely to be present and the impact of the development (see Section 4.2.2). CSZs could also be used to interpret the results of background data searches (see Section 4.2.3).

More information on how these CSZs have been derived can be found on the BCT website.[25]

**Table 3.5 CSZs for different UK bat species.**

| Species | CSZ radius (km) | No. of bats studied | No. of studies | Confidence in zone size[a] |
|---|---|---|---|---|
| Lesser horseshoe[b] | 2 | 83 | 4 | Good |
| Greater horseshoe[b] | 3 | 39 | 4 | Moderate |
| Daubenton's bat | 2 | 7 | 2 | Poor |
| Whiskered/Brandt's bat | 1 | 24 | 1 | Poor |
| Natterer's bat | 4 | 53 | 2 | Good |
| Bechstein's bat[b] | 1 | 70 | 4 | Moderate |
| Noctule | 4 | 20 | 1 | Poor |
| Leisler's bat | 3 | 20 | 2 | Moderate |
| Common pipistrelle | 2 | 23 | 1 | Poor |
| Soprano pipistrelle | 3 | 91 | 3 | Good |
| Nathusius' pipistrelle | 3 | 9 | 2 | Poor |
| Serotine | 4 | 13 | 1 | Poor |
| Barbastelle[b] | 6 | 69 | 3 | Moderate |
| Brown long-eared | 3 | 38 | 1 | Poor |
| Grey long-eared[b] | 3 | 20 | 1 | Moderate |

[a] Confidence is based on the number of bats and number of studies used to inform the calculation of CSZ.
[b] There may be justification with Annex II and other rare species to increase the CSZ to reflect use of the landscape by all bats in a population. We would suggest increasing the CSZ of Bechstein's bat to at least 3km, reflecting its specific habitat requirements.

[25] http://www.bats.org.uk

## 3.8 Species population estimates, distribution and status

Data collected on the presence and abundance of bat species should be assessed in the context of any available knowledge about the distribution and rarity of local, county and national bat populations. Without this context it is not possible to make an assessment about the conservation significance of the survey findings. Potential sources of data on distribution and rarity of bat species are given in Table 3.6.

**Table 3.6 Potential sources of data on species distribution and bat population status at different geographic scales.**

| Geographic scale | Sources of data on species distribution and bat population status at relevant scale |
|---|---|
| Local | Background data search (see Chapter 4 for different sources of data) |
| | Local Biodiversity Action Plans |
| | Local Mammal Atlas |
| | Data from ecological reports submitted with planning applications |
| | Local Records Centre |
| County | County Bat Group |
| | County Wildlife Trust |
| | County Recorder |
| | Local Records Centre |
| Country | Article 17 Reporting[26] |
| UK / Great Britain | Article 17 Reporting |
| | National Bat Monitoring Programme |
| | Richardson, 2000 |
| | Harris and Yalden, 2008 |
| | Dietz *et al.*, 2011 |
| | Wray *et al.*, 2010 |

## 3.9 Species-specific considerations

A few bat species are difficult to detect with bat detectors because they produce quiet (low amplitude) echolocation calls, have very directional echolocation calls, or sometimes use their eyes or ears rather than echolocation (especially in or close to roosts or when gleaning prey). Longer sampling periods, including the use of automated/static detectors, will increase the likelihood of detecting these species acoustically. Other methods include DNA analysis of droppings (where possible) or advanced bat licence survey techniques (see Chapter 9). Table 3.7 provides information on echolocation call characteristics for species with low-amplitude calls and suggests solutions to overcome this limitation.

**Table 3.7 Bat species that are difficult to detect with bat detectors and methods to overcome this limitation.**

| Species | Echolocation call characteristics which create low likelihood of detection | Potential solutions to this limitation |
|---|---|---|
| Lesser horseshoe bat[a] | Calls are directional at high frequency and are subject to a marked degree of attenuation that reduces potential detection distance and the likelihood of a bat being detected if echolocation calls are received by the microphone significantly off-axis. | Full-spectrum recording is recommended. Deploying an automated/static detector within constrained flight corridors such as tunnels and natural corridors through vegetation that are often used by this species and where flights are concentrated will increase the likelihood of recording bats. |

[26] Member states of the European Union are required to report on the implementation of the Habitats Directive every six years through what is known as Article 17 reporting. Article 17 reports are available for the UK and for England, Wales, Scotland and Northern Ireland separately and include data on population estimates, range, distribution and status of the different bat species, with information taken from a number of sources. The latest reporting at the time of writing was JNCC, 2013 (reporting on the period 2007–2012) and the relevant reports can be found on the JNCC website (http://jncc.defra.gov.uk/page-6387).

| Species | Echolocation call characteristics which create low likelihood of detection | Potential solutions to this limitation |
|---|---|---|
| Bechstein's bat | Calls of *Myotis* species for which call intensity has been measured are of fairly low amplitude (Faure *et al.*, 1990) and are generally frequency modulated (FM – where energy is spread across multiple frequencies). When in woodland this species is likely to spend a proportion of its time high in the tree canopy, making it potentially difficult to detect. | Even if its calls can be recorded, separating Bechstein's bat from other *Myotis* species is difficult (or impossible) by acoustic analysis (Parsons and Jones, 2000; Walters *et al.*, 2012). Catching surveys, aided by an acoustic lure, are likely to be required where there is a reasonable potential for this species to be present (i.e. habitat is suitable and a site is within the known geographic range) if this species may be at risk from a proposal. |
| Barbastelle | Very low-intensity echolocation calls (Goerlitz *et al.*, 2010). Flight is relatively fast, so recordings tend to be of short duration. | Use of broad-band recordable detectors has helped to demonstrate that this species is present more frequently and across a wider range of habitats than previously believed. Calls are often missed by ecologists listening in the field as they are often indistinct, not repeated and masked by calls of other species. It is essential to use recordable detectors with this species. Attempt to intersect bats with detectors on commuting routes, when calls are potentially of higher intensity. |
| Brown or grey long-eared bat | Low-amplitude and FM calls are often used. Foraging bats often make no sound and use eyes or ears to hunt by gleaning (Swift and Racey, 2002). Additionally, difficult to detect whilst foraging in understorey. | Attempt to intercept bats with detectors on commuting routes, when calls are potentially of higher intensity. Night vision or infrared camera equipment can be used to identify long-eared species bats by their distinctive appearance. Inside buildings, placing a detector high up usually increases the number of passes recorded. |

[a] Similar issues for greater horseshoe bat but reduced due to lower-frequency calls than for lesser horseshoe bats.

Recent research by Scott and Altringham (2014) analysed the probability of detection of different species according to the intensity and directionality of their calls in woodland habitats. Table 3.8 provides information on the number of surveys required to achieve 95% certainty of detection of different species on walked transect surveys in the study (in woodland habitats, using Pettersson D500x and D240x detectors and software developed for the project to automatically isolate and identify bat calls). This table is included to illustrate the relative likelihood of picking up different species rather than to recommend the protocol, which was developed specifically for monitoring purposes.

**Table 3.8 Number of surveys required to achieve 95% certainty of detection on walked transect surveys in woodland (Scott and Altringham, 2014).**

| Species | Number of surveys to achieve 95% certainty of detection for walked transect survey |
|---|---|
| Pipistrelle | 1 |
| Brandt's bat | 2 |
| Whiskered bat | 2 |
| Barbastelle | 2 |
| Horseshoe bat | 4 |
| Natterer's bat | 5 |
| Brown long-eared bat | Up to 9[a] |
| Bechstein's bat | 4–6[b] |
| Alcathoe | 2–3[b] |

[a] It may be reasonable to assume that brown long-eared bats are likely to be present in most broadleaved woodland. Alternative methods (such as existing records or trapping surveys) may be more effective if proof of presence is required.
[b] Untested estimate.

Chapter 4

# Preliminary ecological appraisal for bats

## 4.1 Introduction

A project often starts with a preliminary ecological appraisal covering ecological features of interest (although smaller projects may not require all elements of a preliminary ecological appraisal, as discussed below). CIEEM has published *Guidelines for Preliminary Ecological Appraisal* (CIEEM, 2013d). These guidelines acknowledge that there is a wide range of terminology used for such surveys but that their purpose is to:

- establish baseline conditions and determine the importance of ecological features present within the specified area;
- establish any requirements for detailed/further surveys (e.g. for bats);
- identify key project constraints to make recommendations for design options to minimise impacts; and
- identify mitigation measures (as far as possible) and enhancement opportunities.

Preliminary ecological appraisals generally include a desk study and fieldwork, often based on the Phase I survey method (JNCC, 2010). The preliminary ecological appraisal is generally extended to identify habitats present that have the potential to support protected species.

As with all surveys, survey design should be based around the questions that require answers. The main questions with respect to preliminary ecological appraisal for bats generally relate to assessing what the potential impacts of the proposal are on bats both on and off site and include the following:

- Is the site close to any internationally or nationally designated sites for bats or with bats as part of the reason for designation?
- Which species are known from the area, what is their conservation status and what types of habitats are they likely to be found in?
- Are there likely to be species listed in Annex II of the Habitats Directive?
- Are there likely to be species particularly at risk of being impacted by the type of activities proposed?
- What habitat types are present on site and in the surrounding area that are (a) likely to be used by bats for roosting, foraging or commuting, and (b) likely to be impacted by the proposal?
- What is the likely suitability of those habitats for bats?
- How do the habitats on site connect to habitats in the surrounding area to create an ecological network?

In order to answer the questions outlined above, a preliminary ecological appraisal for bats, consisting of a desk study and fieldwork, is generally carried out. This is described in the following sections. This assessment will enable an ecologist to proceed with further bat surveys as necessary using an iterative approach where each stage informs the next.

A full preliminary ecological appraisal for bats may not be necessary for smaller projects (e.g. projects impacting a single house or barn). Relevant elements, such as a study of maps, aerial photographs and site photographs, may provide enough information to skip straight to a preliminary roost assessment (see Chapters 5 and 6) without a preliminary ecological appraisal and with elements of the desk study (such as a background data search from a Local Records Centre (LRC)) carried out afterwards if potential for bats or evidence of bats is found. This is likely to save both time and financial resources.

## 4.2 Preliminary ecological appraisal – desk study

### 4.2.1 Sources of information for desk study

The aim of a desk study for bats is to collate and review existing information about a site and its surroundings to inform the design of subsequent bat surveys and inform the impact assessment for the project.

When using or referring to materials obtained from external sources, rules of copyright should be noted and adhered to. There may also be restrictions on the commercial use of Internet resources.

This information includes the following:

- Photographs and descriptions of the site.
- Maps and aerial photographs can be viewed using applications such as Google Maps[27] or Bing Maps,[28] both of which also provide a street view option. These allow an ecologist to identify habitats and features that are likely to be important for bats and assess their connectivity. Note when the photographs were taken; if old, conditions may have changed.
- Records of statutory and non-statutory designated sites (where bats form all or part of the reason for the designation) can be found on the Multi Agency Geographic Information for the Countryside (MAGIC) website,[29] although less information is provided for Scotland. Scottish users should refer to the SNH site link system.[30]

[27] https://www.google.co.uk/maps/
[28] https://www.bing.com/maps/
[29] https://www.magic.defra.gov.uk
[30] https://gateway.snh.gov.uk/sitelink/

It is usually necessary to contact the LRC or LPA to obtain records of non-statutory sites such as County Wildlife Sites or Sites of Importance for Nature Conservation; these are often designated for botanical reasons but their descriptions can provide useful information about habitats and may contain records of bats. LRCs are found in most counties and generally charge a fee to search for records of designated sites and protected species. A list of active centres can be found on the website of the National Forum for Biological Recording (NFBR).[31]

- Records of bats in the area can be obtained from a number of organisations by providing a grid reference or site boundary and stating the required radius for the search and the type of records required. It is important to note that the absence of bat records does not confirm the actual absence of bats because records are not always collected in a systematic and thorough way. Organisations that hold local bat records are listed below.
  - National Biodiversity Network (NBN).[32] The use of NBN data in commercial ecological reports is not permitted under the NBN code of conduct.[33]
  - LRCs (see above).
  - LBGs – found in most counties, sometimes have a database of records or a county bat distribution atlas, will sometimes carry out a background data search for a fee although many share their records with LRCs, may also provide information on the local and regional status of populations; contact details for each LBG can be obtained from the BCT website[34] (search for 'local bat groups').

Other sources of bat records or information may include the following:

  - County Ecologists (or Biodiversity or Nature Conservation Officers) – employed by some local, county or district councils.
  - Local Wildlife Trusts (LWTs).[35]
  - County mammal recorders – volunteers who collate records of mammal sightings in their county; contact details are available from the Mammal Society website.[36]
  - Local publicly funded research projects, e.g. data from all Natural Environment Research Council funded research projects on bats are published/available free of charge online.
  - Other planning applications for the area – may provide some insight into local bat species and activity levels; planning applications can be found on county/district/borough council websites.
  - The MAGIC website[37] now provides information on EPS licences.
  - Local or national mining history or caving groups and clubs, and caving councils – these may have useful information on hibernation roosts and some cave systems have biological recorders who publish records in club or regional journals; see the BCA's website[38] for information.
  - On-site personnel such as site security guards, caretakers or gardeners – may provide anecdotal evidence that gives useful pointers, although data may not be reliable enough to be used in a preliminary ecological appraisal.

- Other relevant literature – for example, species distribution and status (see Section 3.8). This information is particularly important when analysing survey data and carrying out an impact assessment.

### 4.2.2 Geographical extent of desk study

As a minimum, it is recommended that background data searches should be carried out up to 2km from the proposed development boundary (including all temporary works). However, the data search should be related to the scheme's ZoI (see Section 2.2.3) and consider the CSZs of species likely to be present (see Section 3.7), and may need to extend up to 10km for larger projects.

Statutory designated sites such as SACs or SSSIs relevant to bats within 10km should also be considered.

Some other considerations that should be applied to background data searches are as follows:

- In areas where bat roosts and foraging areas are more sparsely distributed, the background data search radius may need to be increased.
- In coastal areas, migrating bats may need to be considered. Ringing has now confirmed that some of our bat species migrate between the UK and the continent.[39]

### 4.2.3 Interpretation of desk study data

The desk study records provide contextual information for the survey design stage as well as the evaluation of the survey results. They should be interpreted to identify:

- if proposed activities are likely to impact on a SAC or the qualifying feature of a SAC (this may trigger the need for a HRA);
- if the proposed activities are likely to impact on other designated sites and thus require consultation with relevant bodies;[40]
- any species (or genera) confirmed/thought to be present;
- any bat roosts that will be impacted (on or off-site);
- if it is likely that the CSZs of bats from roosts off-site will be impacted (see Section 3.7);
- if there are any rare species in the area that may require species-specific survey methodologies.

### 4.2.4 Next steps

It is usual for a desk study to be followed by the fieldwork element of a preliminary ecological appraisal (although, as discussed above, this may not be needed for smaller projects).

There may be some cases where aerial photographs and descriptions of the site confirm there is no habitat suitable for bats on site or in

31 https://www.nfbr.org.uk
32 https://www.nbn.org.uk
33 https://data.nbn.org.uk/Terms
34 https://www.bats.org.uk
35 https://www.wildlifetrusts.org
36 https://www.mammal.org.uk
37 https://www.magic.defra.gov.uk
38 https://www.british-caving.org.uk
39 A Nathusius' pipistrelle that was ringed near Bristol in the UK in 2012 was subsequently found in the Netherlands, 600km away (Hargreaves, 2014). Other evidence is emerging that supports the theory that bat species migrate between the UK and the continent (BSG Ecology, 2013a, 2014a, b).
40 NE has developed the concept of Impact Risk Zones (IRZs) around SSSIs. They define zones around each SSSI (found here: http://magic.defra.gov.uk/MagicMap.aspx) which reflect the particular sensitivities of the features for which it is notified and indicate the types of development proposal which could potentially have adverse impacts. The IRZs also cover the interest features and sensitivities of European sites. More information on IRZs can be found here: https://www.gov.uk/construction-near-protected-areas-and-wildlife

the surrounding area. Ecologists and their clients may want to keep a record of the rationale behind the decision not to survey.

## 4.3 Preliminary ecological appraisal – fieldwork

### 4.3.1 Description and aims

A preliminary ecological appraisal for bats is a walkover of the proposed development site to observe, assess and record any habitats suitable for bats to roost, commute and forage both on site and in the surrounding area (it is important that connectivity within the landscape is also considered at this stage). The aim is to determine the suitability of a site for bats, to assess whether further bat surveys will be needed and how those surveys should safely be carried out.

### 4.3.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 4.3.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. Unless an ecologist intends to enter buildings or investigate PRFs in trees with a torch or endoscope, a preliminary ecological appraisal is unlikely to cause disturbance so a licence is generally not needed.

### 4.3.4 Methods

Ecologists should identify and record any structures and trees that could be suitable for bats to roost in and any habitats that could be suitable for bats to commute, forage or swarm in/at. If suitability is assessed at this stage, the scheme presented in Table 4.1 should be used. Please note that low suitability roosting habitats may be present in commuting/foraging habitats that are of high suitability, and vice versa. Roosting habitats and commuting/foraging habitats should be assessed separately and independently.

**Table 4.1 Guidelines for assessing the potential suitability of proposed development sites for bats, based on the presence of habitat features within the landscape, to be applied using professional judgement.**

| Suitability | Description<br>Roosting habitats | Commuting and foraging habitats |
|---|---|---|
| Negligible | Negligible habitat features on site likely to be used by roosting bats. | Negligible habitat features on site likely to be used by commuting or foraging bats. |
| Low | A structure with one or more potential roost sites that could be used by individual bats opportunistically. However, these potential roost sites do not provide enough space, shelter, protection, appropriate conditions[a] and/or suitable surrounding habitat to be used on a regular basis or by larger numbers of bats (i.e. unlikely to be suitable for maternity or hibernation[b]).<br><br>A tree of sufficient size and age to contain PRFs but with none seen from the ground or features seen with only very limited roosting potential.[c] | Habitat that could be used by small numbers of commuting bats such as a gappy hedgerow or unvegetated stream, but isolated, i.e. not very well connected to the surrounding landscape by other habitat.<br><br>Suitable, but isolated habitat that could be used by small numbers of foraging bats such as a lone tree (not in a parkland situation) or a patch of scrub. |
| Moderate | A structure or tree with one or more potential roost sites that could be used by bats due to their size, shelter, protection, conditions[a] and surrounding habitat but unlikely to support a roost of high conservation status (with respect to roost type only – the assessments in this table are made irrespective of species conservation status, which is established after presence is confirmed). | Continuous habitat connected to the wider landscape that could be used by bats for commuting such as lines of trees and scrub or linked back gardens.<br><br>Habitat that is connected to the wider landscape that could be used by bats for foraging such as trees, scrub, grassland or water. |
| High | A structure or tree with one or more potential roost sites that are obviously suitable for use by larger numbers of bats on a more regular basis and potentially for longer periods of time due to their size, shelter, protection, conditions[a] and surrounding habitat. | Continuous, high-quality habitat that is well connected to the wider landscape that is likely to be used regularly by commuting bats such as river valleys, streams, hedgerows, lines of trees and woodland edge.<br><br>High-quality habitat that is well connected to the wider landscape that is likely to be used regularly by foraging bats such as broadleaved woodland, tree-lined watercourses and grazed parkland.<br><br>Site is close to and connected to known roosts. |

[a] For example, in terms of temperature, humidity, height above ground level, light levels or levels of disturbance.
[b] Evidence from the Netherlands shows mass swarming events of common pipistrelle bats in the autumn followed by mass hibernation in a diverse range of building types in urban environments (Korsten *et al.*, 2015). This phenomenon requires some research in the UK but ecologists should be aware of the potential for larger numbers of this species to be present during the autumn and winter in large buildings in highly urbanised environments.
[c] This system of categorisation aligns with BS 8596:2015 Surveying for bats in trees and woodland (BSI, 2015).

Assessment of suitability, carried out as per the table above, informs the design of subsequent survey work, although the elements outlined in Section 2.2 should also be considered, in particular the potential impacts (Section 2.2.2) and proportionality (Section 2.2.5). The assessment of suitability will be further refined for roosts during a preliminary roost assessment (Sections 5.2 and 6.2). These assessments inform subsequent survey effort for roosts (see Sections 7.1.7 and 7.1.8) and commuting and foraging habitats (see Section 8.2.7). The early assessment of suitability for bats, however, should not be confused with the later assessment of the conservation value of a site, which relates to the species, numbers and roost types **actually present**.

During the preliminary ecological appraisal, the ecologist should consider the further surveys needed (if any), their logistics (resources, emergence survey locations, transect routes, static detector locations, timings), and any potential health and safety hazards reported.

If no suitable habitat for bats is found, then further surveys are not likely to be necessary. Ecologists and their clients may want to keep a record of the rationale behind the decision not to carry out further surveys, including evidence that an adequate assessment has been made by a suitably qualified ecologist and the conclusion is reasonable.

### 4.3.5 Timing

A preliminary ecological appraisal survey for bats should be done during daylight; sufficient time should be allowed to walk the entire site. It may be necessary to use multiple ecologists if only a limited amount of time is available and the site is very large.

The survey can be done at any time of year but it is recommended that at least some of the results of the desk study are available to assist in planning and carrying out the survey and before making decisions about subsequent surveys.

### 4.3.6 Survey effort

The survey area should be determined by the ZoI and the nature of the proposals.

### 4.3.7 Weather conditions

The preliminary ecological appraisal can be carried out under any weather conditions, providing that the weather conditions do not affect the ecologist's ability to carry out the survey effectively and safely.

### 4.3.8 Next steps

The preliminary ecological appraisal informs the design of subsequent, more detailed surveys. The following questions should be considered:

- Are further, more detailed bat surveys needed?
- What types of detailed bat surveys would be appropriate to enable the impact assessment that is needed relative to the nature and current status of the project?
- Are any specialist techniques required arising from the potential presence of particular species; for example, the use of acoustic lures to detect the presence of Bechstein's bat?
- Are any specialist techniques required arising from the presence of particular habitats: for example, the need for confined spaces training to access underground sites?
- Are any specialist techniques required arising from the potential for project-specific impacts; for example, the need to survey at crossing points on a proposed road scheme or at height?

Where further surveys and mitigation are required, the preliminary ecological appraisal report in isolation will not be adequate for submission to an LPA in support of a planning application. The report will only be adequate for this purpose if there is no need for further surveys and mitigation.

Chapter 5

# Bat roost inspection surveys – buildings, built structures and underground sites

## 5.1 Introduction

This chapter provides information on carrying out inspection surveys for bat roosts in buildings, built structures and underground sites, collectively referred to as structures.

These surveys may be required where development proposals include demolition of a structure or a structure will be modified in such a way that bats or their roosts could be *directly* impacted if present.

These surveys may also be needed where bats roosting in a structure could be *indirectly* impacted by development activities outside the roost such as lighting/removal of vegetation or the construction of a new road/railway, where collision impacts are a possibility. In these cases it is necessary to consider whether bat roosts both on and off site may be indirectly impacted and consider surveying at least for maternity and hibernation roosts and swarming sites where appropriate.

The above principles apply regardless of the size of the development.

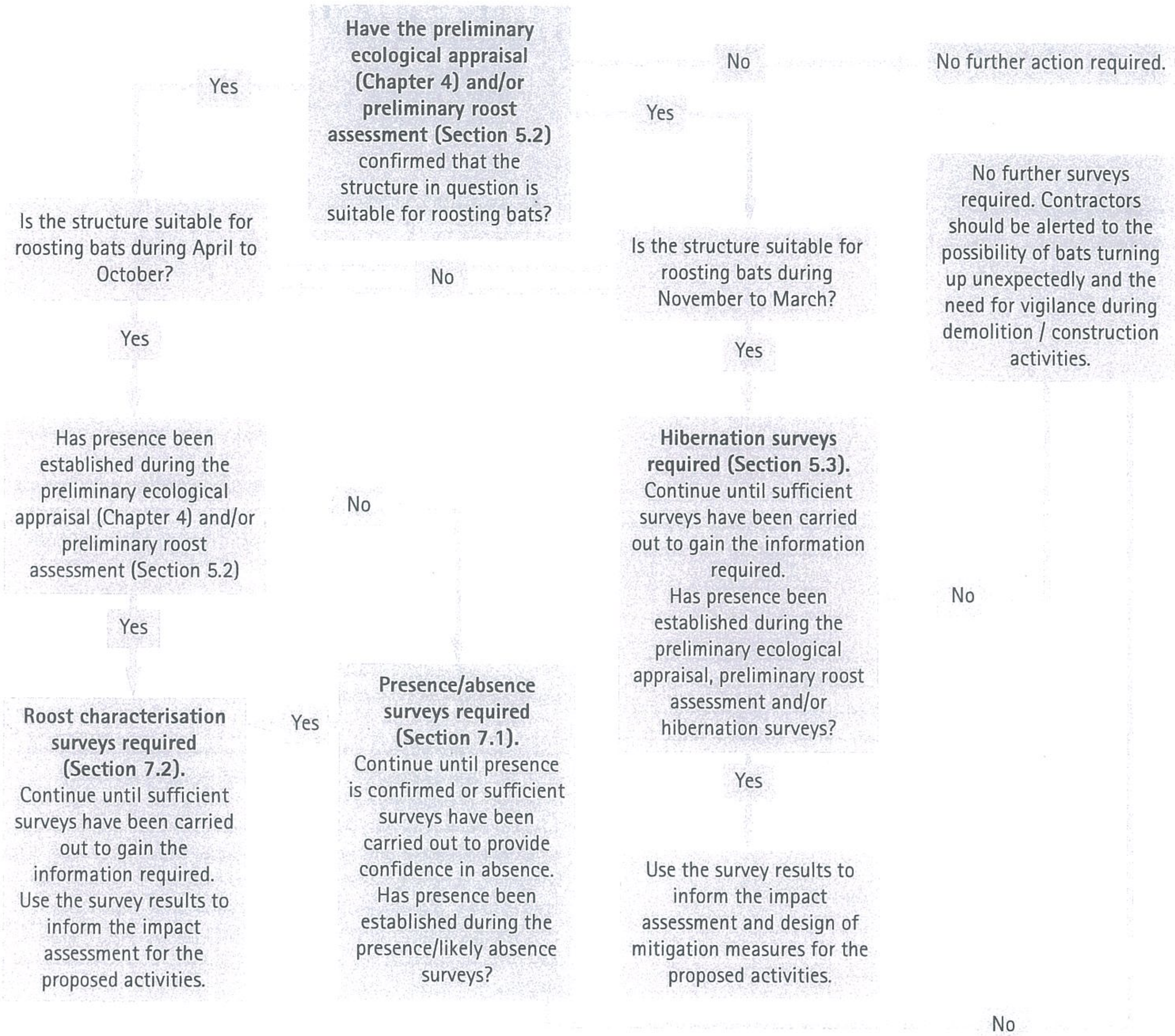
Roost surveys of structures should be designed to answer specific questions, such as:

- Are actual or potential bat roosts present (and if so, where)?
- Which bat species use the site for roosting?
- How many bats do these roosts support?
- Where are the bat roost access points?
- Where are the bat roosts and how do the bats get to them from the access points?
- What is the current arrangement of vegetation and lighting in relation to the access points?
- At what times of the year are bats present? How does use change seasonally?
- What types of bat roost (see Section 3.3) are present?

Answering some or all of these questions allows an ecologist to carry out an impact assessment and design a mitigation, enhancement and monitoring strategy, where relevant.

Roost surveys of structures generally take a staged approach, with the first step being a **preliminary roost assessment** (possibly preceded by a preliminary ecological appraisal – see Chapter 4), which may be followed up by **winter hibernation**, **presence/absence** and/or **roost characterisation surveys**. The latter two survey types are covered in Chapter 7, which also covers trees. Survey design should be iterative; each stage informing the next, as per the flow chart provided in Figure 5.1. The effectiveness of the surveys should be considered at each stage.

**Figure 5.1 Flow chart illustrating the process used to establish which types of surveys are necessary for roosts in structures.**




Note on Figure 5.1: In some situations bats may use the same structure throughout the year and in these situations, both arms of the flow chart need to be fully considered.

## 5.2 Preliminary roost assessment – structures

### 5.2.1 Description and aims

A **preliminary roost assessment** is a detailed inspection of the exterior and interior of a structure to look for features that bats could use for entry/exit and roosting and to search for signs of bats. The aim of this survey is to determine the actual or potential presence of bats and the need for further survey and/or mitigation. In many situations it is not possible to inspect all locations where bats may be present and therefore an absence of bat evidence does not equate to evidence of bat absence.

### 5.2.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

PPE for entering confined spaces, entering spaces with asbestos, working at height or working in derelict buildings may also be required but specialist advice and training should be sought in such scenarios. More on health and safety can be found in Section 2.7.

### 5.2.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. The fieldwork involved in a preliminary roost assessment could result in disturbance to bats and therefore it is good practice for ecologists to hold a survey licence. The use of endoscopes requires specific training and the relevant licence; in England this would be a Class Two licence (see Section 1.2.2). Bat handling should only be carried out by ecologists licensed to handle bats or their trainees and only when the information cannot be gained by any other method. Hibernating bats, heavily pregnant bats or bats with dependent young should not be handled.

Training relating to health and safety may also be required for preliminary roost assessments; examples include the safe use of ladders or asbestos awareness training (see Section 2.7).

### 5.2.4 Methods

The method involves a detailed external and internal inspection of the structure to compile information on potential and actual bat entry/exit points; potential and actual bat roosting locations; any evidence of bats found and the number of ecologists that will be required for any subsequent surveys. The *Bat Workers' Manual* (Mitchell-Jones and McLeish, 2004) provides useful diagrams and definitions of architectural terms.

Sufficient time should be allowed to complete the external and internal inspection during daylight hours. The inspection should be carried out systematically and consistently through all parts of the structure and the results recorded in a standard format.

Definitions of suitability of roosting habitat are provided in Table 4.1 (page 35). The evaluation at this stage is more precise than during the preliminary ecological appraisal (see Chapter 4).

#### 5.2.4.1 External survey

A systematic search should be made of the exterior of the structure to identify potential or actual bat access points and roosting places (although it should be noted that some may not be visible from ground level) and to locate any evidence of bats such as live or dead specimens, bat droppings, urine splashes, fur-oil staining and/or squeaking noises. Bat specimens and droppings are the most reliable type of evidence; the other types are not always the result of bat activity. **Sometimes bats leave no visible sign of their presence on the outside of a building (and even when they do, wet weather can wash evidence away).**

The search should include the ground, particularly beneath potential access points, any windowsills, window panes, walls, behind peeling paintwork or lifted rendering, hanging tiles, weatherboarding, eaves, soffit boxes, fascias, lead flashing, gaps under felt (even including those of flat roofs), under tiles/slates and in existing bat boxes. Any gaps in brickwork or stonework should be identified and searched because they may allow access to cavity- or rubble-filled walls. **This list is not exhaustive – all areas should be searched thoroughly and systematically.**

The status of the structure (with respect to structural integrity) should be established prior to the visit but, during the external survey, this information should be corroborated and any new information added to the risk assessment. This assessment is essential to ensure safety when entering a structure.

#### 5.2.4.2 Internal survey

Where safe, a systematic search should be made of the interior of the structure to identify potential or actual bat access points and roosting places and to locate evidence of bats. Bat specimens (live or dead) and droppings are the most reliable type of evidence. Other evidence found can include urine splashes, fur-oil staining, feeding remains (moth wings), squeaking noises (which can sometimes alert an ecologist to an otherwise hidden roost), bat-fly (Nycteribiid) pupal cases (Hutson, 1984) or odour. These latter types of evidence should, however, not be relied upon in isolation to confirm presence. **Sometimes bats leave no visible sign of their presence even on the inside of a building, particularly where there are hidden cracks, crevices and voids.**

Ecologists should work quietly and check structures in a systematic manner, working upwards from the entrance and checking any cellar space last. Upon entering an individual space, the places bats are most likely to be should be checked first. For example, on entering a loft space, always look up and check the ridge beam and other beams for free-hanging bats first. Following this, the space should be checked systematically for evidence of bats.

In derelict or abandoned structures, all areas should be surveyed where it is safe to do so. Before entering upper floors or attics, the ceilings below should be inspected for any damage/concealed hatches that may indicate it is unsafe to walk above. It may also be necessary to seek professional advice (e.g. from a structural engineer) as to the safety of a building before entering or proceeding to upper floors and attics.

Where buildings are in use for residential or commercial purposes, it may not be necessary to inspect all of the rooms, instead concentrating on upper floors (evidence stuck to exterior windows, walls and windowsills may be more apparent from upper rooms than from the ground-level survey), roof spaces, boiler rooms or other dark spaces or spaces not in daily use.

Within rooms in buildings, ecologists should inspect:

- the floor and surfaces of any furniture or other objects;
- behind wooden panelling;
- in lintels above doors and windows;
- behind window shutters and curtains;
- behind pictures, posters, furniture, peeling paintwork, peeling wallpaper, lifted plaster and boarded-up windows; and
- inside cupboards and in chimneys accessible from fireplaces.

Frequently used roost locations within roofs include:

- the top of gable end or dividing walls;
- the top of chimney breasts;
- ridge and hip beams and other roof beams;
- mortise and tenon joints;
- all beams (free-hanging bats);
- the junction of roof timbers, especially where ridge and hip beams meet;
- behind purlins;
- between tiles and the roof lining; and
- under flat felt roofs.

Therefore a search of a roof void should pay particular attention to the floor, water tanks, stored materials and other surfaces beneath such locations to look for evidence of bats. Searching beneath and around the edges of insulation may also uncover historical evidence of bats as listed above. Any internal access to cavity or rubble-filled walls should be noted along with the range of conditions provided by a structure.

**The above lists are not exhaustive – the ecologist should use professional judgement based on experience to decide where inspection is necessary.**

Turning all torches off whilst in a dark space (e.g. a roof space or dark barn) will allow ecologists to look for light spilling in, which will indicate gaps that bats may use for entry points.

Sometimes a space may have been cleaned and evidence of bats may have been removed so this needs to be taken into consideration.

If any parts of a structure cannot be surveyed due to accessibility, this, and any other limitations of the inspection, should be clearly detailed in the report.

The following sections provide information on some structure-specific considerations.

**5.2.4.3 Timber-framed and stone barns**

Timber-framed and stone barns may be used by bats throughout the year, and can support a range of roost types for a variety of different species. Barns are often very open and tall, making preliminary assessment and detailed surveying of potential roost sites difficult and time-consuming. They may also contain farm machinery and other materials that can impede bat surveys.

When surveying barns, the features that should be given particular attention during an inspection survey include:

- gaps between ridge tiles and ridge and roof tiles, usually where the mortar has fallen out or the tiles are broken or lifted;
- the ridge area of the roof (particularly between the ridge beam and roofing material);
- lifted lead flashing associated with roof valleys, ridges and hips, or where lead flashing replaces tiles;
- spaces between external weatherboarding/cladding and the timber frame or walls;
- gaps behind window frames, lintels and doorways including the main doors;
- tenon and mortise joints between truss beams and braces and the principal support columns;
- cracks and crevices in timbers;
- gaps between stones or bricks (especially where purlins enter the wall and by the wall plate); and
- surfaces such as the ground, ledges, windows, sills or walls, machinery or stored material within the barns (which should be searched for bat droppings and/or urine spots or stains).

Close inspection of cavities and behind timbers should be undertaken using endoscopes, torches and/or mirrors. This often requires the use of ladders to access a safe working platform. Inspection of the roof timbers and ridge beam often requires binoculars and powerful torches to illuminate the roof from the ground.

**5.2.4.4 Churches**

Churches, because of their age, structure and location, often support bats. Survey considerations that are specific to churches are given below.

- Bats may share the main spaces of a church with worshippers (even if there is a separate roof void), therefore the internal survey should include all areas.
- Most churches are regularly cleaned, so bat droppings may be removed. Ask the cleaning staff if they are aware of any bats, find out the cleaning schedule and do not carry out a preliminary roost assessment immediately after the church has been cleaned. Search higher areas out of the reach of cleaners for evidence of bats.
- Urine splashes can leave a permanent and obvious stain on polished wooden, stone and metal surfaces. However, stains can persist for many years and so do not always indicate recent use of the church by bats.
- Features of churches are given specific terms: use the correct technical terminology in recording and reporting. The *Bat Workers' Manual* (Mitchell-Jones and McLeish, 2004) provides useful guidance, including diagrams.
- Churches may have underground crypts that are not immediately obvious but often support bats; enquire about the existence of underground spaces and gain access for inspection.

**5.2.4.5 Bridges**

Many bridges cross watercourses or other linear features providing, on their verges, commuting and foraging habitats for bats. This means that many bridges are used for roosting. Some examples are given in Billington and Norman (1997). Survey considerations that are specific to bridges are given below.

- Bats roost in many different locations within old and new bridges. Features offering potential include any holes, cracks and crevices leading to voids, particularly where there is clear access.
- Roosting locations in which bats have been recorded in bridges include expansion joints; gaps at the corner of buttresses; widening gaps; cracks and crevices between stonework and brickwork where mortar has fallen out; drainage pipes and ducts; and internal voids within box girder bridges.
- Features of bridges are given specific terms: use the technical terminology in recording and reporting. The *Bat Workers' Manual* (Mitchell-Jones and McLeish, 2004) provides useful guidance, including diagrams.
- Bridges require specific health and safety consideration because they are often associated with watercourses, roads or railway lines. Access for survey may require a boat; scaffolding; a mobile elevating work platform (MEWP); a Permit to Work; Personal Track Safety training and qualification; or a Track Visitor Permit (TVP). Survey may even require a road or rail closure. Confined spaces training may be required to access box girder bridges. All requirements should be discussed with the client and agreed with the relevant operating authority.

**5.2.4.6 Underground sites**

Underground sites can provide the specific microclimatic conditions that bats favour during hibernation in the winter (although they may also be used at other times of the year). A preliminary roost assessment carried out at any time of year can assess the potential for winter use, look for droppings (which can be subjected to DNA analysis for species identification) and other signs and look for bats using the site at other times of the year. However, only the winter hibernation surveys will provide information on numbers of hibernating bats. This section describes the considerations required for a preliminary roost assessment and Section 5.3 provides information on how to carry out a winter hibernation survey. The site in question may also be suitable for swarming bats; see Section 8.3 for survey methods.

- A level two class bat survey licence is required to enter known bat hibernation sites in England and in the other UK countries hibernation surveys are not included on all survey licences. It is essential that ecologists entering sites where bats are hibernating have the appropriate licence to do so.
- Ecologists entering hibernacula should be familiar with the latest information and guidance on white-nose syndrome; see Section 5.3.4 (Box 2).
- The LBG or National Bat Monitoring Programme may be aware of the site and carrying out regular monitoring already.
- It is advisable to consult mining history organisations, the BCA[41] or local caving groups before undertaking visits to natural caves and abandoned mines. These organisations frequently have important site-specific information about safety precautions, site layout, history, records of bats and details of any access agreements.
- The BCA has a Cave Conservation Code, which is downloadable from their website.[42]
- Caving groups may be available to provide training or practical assistance for survey work.
- Entering underground sites may require Confined Spaces Training or rope access. A full risk assessment should be carried out and often a method statement is also required. Equipment and training specific to the site should be identified and obtained.
- Underground sites beneath buildings, such as cellars, may be more readily accessible to ecologists than caves and mines and therefore require a different approach.

### 5.2.5 Complementary methods

Where bat droppings are present, samples should be carefully collected for DNA analysis (see Appendix 4 for collection protocol) unless species identification has been reliably established by other means such as observation of bats in the roost or from echolocation calls. Some species groups, for example those from the genus *Myotis* and *Plecotus*, are difficult to tell apart by these methods (Parsons and Jones, 2000; Walters *et al.*, 2012), so DNA analysis of their droppings may be necessary. DNA analysis of droppings is a more reliable method than identifying droppings by their shape, texture or colour, which can be variable and overlaps between species. Various organisations offer this service. Fabric or plastic sheets can be placed down in structures to collect droppings for this purpose on subsequent survey visits.

As a last resort, it may be possible to capture bats by hand and handle them in order to identify their species, gender and age during a preliminary roost assessment (see comments in Section 5.2.3 in relation to licensing and when handling bats is inappropriate).

### 5.2.6 Timing

Preliminary roost assessments can be carried out at any time of year providing any related limitations are recognised and reported.

If a maternity roost is identified, disturbance should be minimised during June and early July, when females are heavily pregnant or dependent young are present. Similarly, if a hibernation site is discovered then any subsequent disturbance should be minimised during the coldest months of December to February. Further information about these roosts can be gained from DNA analysis of bat droppings collected outside these sensitive periods (to establish species). Roost characterisation surveys (see Section 7.2) can be used to gain more information about maternity roosts and hibernation visits should be kept to a minimum (see Section 5.3).

### 5.2.7 Survey effort

The time needed for a preliminary roost assessment will vary according to the complexity of the structure and the number of ecologists deployed. Large structures with multiple roof spaces, multiple human access points and/or abundant voids and crevices will clearly take some time to understand and search thoroughly. Also, structures may contain several different bat roosts of different species each with their own access point and used at different times of the year. This all adds time to the survey.

As a guide, an internal inspection of a single roof area of a four-bedroom domestic property is likely to take one ecologist (with an assistant remaining outside the loft) approximately one to two hours; an internal inspection of a traditional timber-framed farm building may take one ecologist plus assistant between four hours and one day; an internal inspection of a large complex building such as a former hospital or stately home, with numerous roof voids and buildings, is likely to take one ecologist plus assistant several days. This is, of course, heavily dependent on the individual situation.

It is often difficult to have confidence in negative preliminary roost assessment survey results. For example, evidence of bats can be weathered away or bats could roost in inaccessible cracks and crevices, leaving little or no external evidence. It may therefore be necessary to spend more time searching and employ equipment such as mirrors and endoscopes.

### 5.2.8 Weather conditions

Preliminary roost assessments can be carried out under any weather conditions providing the survey is safe and any related limitations are recognised and reported.

### 5.2.9 Next steps

**Where the possibility that bats are present cannot be eliminated or evidence of bats is found during a preliminary roost assessment, then further surveys (such as winter hibernation (Section 5.3), presence/absence (Section 7.1) and/or roost characterisation (Section 7.2) surveys) are likely to be necessary if impacts on the roosting habitat (or the bats using it) are predicted.** The ecologist should consider the further surveys needed (if any), their logistics (resources, emergence survey locations, timings), and any potential health and safety hazards reported.

**If the structure has been classified as having low suitability for bats (see Table 4.1), an ecologist should make a professional judgement on how to proceed based on all of the evidence available.**

[41] http://british-caving.org.uk/
[42] http://british-caving.org.uk/wiki3/doku.php?id=conservation_access:cave_conservation_code

If sufficient areas (including voids, cracks and crevices) of a structure have been inspected and no evidence found (and is unlikely to have been removed by weather or cleaning or be hidden) then further surveys may not be appropriate. Information (photographs and detailed descriptions) should be presented in the survey report to justify this conclusion and the likelihood of bats being present at other times of the year estimated. If there is a reasonable likelihood that bat roosts could be present, and particularly if there are areas that are inaccessible for survey, then further surveys may be needed and these should be proportionate to the circumstances (see Section 2.2.5).

**If no suitable habitat for bats is found, then further surveys are not necessary.** In this scenario, it is necessary to document how this decision has been reached; photographs and detailed descriptions should be made available as evidence of a robust survey and assessment.

## 5.3 Winter hibernation surveys – structures

### 5.3.1 Description and aims

A **winter hibernation survey** includes a detailed inspection of a structure during the winter to look for and identify hibernating bats or other evidence of bat occupation. This survey will be necessary if potential has been identified for a structure to support hibernating bats (during the preliminary ecological appraisal (Chapter 4) or preliminary roost assessment (Section 5.2)) and the structure is likely to be impacted by proposed activities.

It should be noted that sites used for hibernation may also be used by bats at other times of the year and therefore other surveys may also be necessary.

### 5.3.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 5.3.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. A winter hibernation survey could cause disturbance to bats and therefore it is good practice for ecologists to hold a survey licence. Standard survey licences for hibernacula do not permit handling of hibernating bats and this is only rarely permitted by a specific project licence. The handling of hibernating bats should therefore be avoided[43] except in the event of an emergency where the bat is in danger.

Training relating to health and safety may also be required for hibernation surveys; examples include the safe use of ladders or confined spaces training (see Section 2.7).

### 5.3.4 Methods

This type of survey requires close and systematic inspection of all cracks, crevices and voids for hibernating bats using torches, mirrors and endoscopes. With the exception of horseshoe bats, which usually hang freely from the walls and ceilings of hibernacula, hibernating bat species are often under-recorded because they crawl deep into crevices and can be difficult to find. Their presence is sometimes given away by droppings or oil staining around cracks and crevices or droppings beneath.

Bats periodically arouse to drink, as well as to feed if it is warm enough for insects to be active. Arousal may also be triggered by disturbance through increased levels of noise, light or heat, which may result from the presence of ecologists (therefore the number of ecologists and the amount of time they are present should be minimised). The disturbance is not always obvious to the observer at the time, as bats do not necessarily arouse immediately. There is evidence that the longer the bats have been in a torpid state, the more sensitive they are to arousal stimuli (Thomas, 1995). Bats should therefore be identified with minimal disturbance. The location and species (or genus) of all bats should be marked on a map of the structure.

Identification can be challenging because often only part of the bat can be seen. Experience is essential to gain as much information in as short a time as possible. If it is only possible to identify the bats to genus level (for example, with the *Myotis* species) then it may be possible to gain positive identification through other methods such as DNA analysis of droppings or collection of acoustic data (see Section 5.3.5).

The presence of any significant accumulations of droppings, *Nycteribiid* pupal cases (Hutson, 1984) and stained or marked areas should be recorded, as these may indicate the presence of large numbers of bats at other times of the year. Further visits during different seasons may be required in such situations to assess use of the site.

Ecologists entering hibernacula should familiarise themselves with the latest information on white-nose syndrome, provided in Box 2 (below).

[43] Handling hibernating bats has been shown to have a detrimental effect (Speakman *et al.*, 1991).

**Box 2 White-nose syndrome and bats in the UK.**

White-nose syndrome (WNS) is a disease caused by the fungus *Pseudogymnoascus destructans*. It affects hibernating bats in eastern North America, where it has caused the death of millions of bats since it was first discovered in 2006. Symptoms of WNS are:

- visible white fungus *(P. destructans)*, around the nose, ears, wings and/or tail membrane;
- bats clustered near the entrances of hibernacula, or in areas not normally identified as winter roost sites;
- bats flying outside during the day in temperatures at or below freezing; and
- dead or dying bats in or near hibernation sites.

Whilst the fungus associated with the syndrome has been identified on bats from at least 15 European countries since 2009, none of the other symptoms have been recorded and therefore there is no WNS in Europe (the fungus may have evolved but UK bats have an immunity that the North American species affected do not).

The fungus has been isolated from two live bats in the UK and from a number of environmental samples but as with the rest of Europe there is no evidence of WNS. BCT provides guidance for bat workers undertaking hibernation surveys and surveyors should remain vigilant and report any suspected cases of either the fungus or WNS to BCT and observe appropriate decontamination procedures. For more information refer to the WNS pages on the BCT website.[44]

### 5.3.5 Complementary methods

See Section 5.2.5 and Appendix 4 regarding the collection of droppings for DNA analysis. This can be particularly useful in situations where species identification is not possible because bats are tucked too far into crevices for ecologists to see their diagnostic features.

Deploying automated/static bat detectors can be useful in gaining information about hibernating bats (although the echolocation calls of *Myotis* species are notoriously difficult to separate (Parsons and Jones, 2000; Walters *et al.*, 2012)). Because the detectors can be left for long periods of time they are more likely to pick up bats when they become active, which may be particularly useful at sites with deep crevices that cannot be inspected. Detectors should ideally be deployed with temperature and humidity loggers to provide context (in terms of environmental conditions) for the survey results collected.

### 5.3.6 Timing

A survey at any time of year may indicate the suitability of a site for hibernation and the presence of droppings only will confirm that the site is used by bats (although an absence of droppings does not confirm absence) but further surveys may be required to determine when and how bats use the site.

The period during which bats hibernate in any given winter depends on factors such as ambient temperature, humidity and species. Some species, notably barbastelle and brown long-eared, may only hibernate for extended periods when temperatures fall below freezing. Bats can hibernate any time between November and March, depending on the prevailing weather conditions and location. Different sites are likely to be used at different times, dependent on the types of conditions they offer.

The highest numbers of bats in underground hibernacula are usually found in January. During the winter, individual bats move around to sites that present the optimum environmental conditions for their age, sex and body weight. Many species are only found in underground sites when the weather is particularly cold and therefore surveys to detect bats are most appropriate from December to February.

### 5.3.7 Survey effort

Because winter surveys may disturb hibernating bats, visits should be limited to the minimum necessary to gain the required information. If it is necessary to assess the numbers of bats using a site, a minimum of two visits is recommended, one in mid-January and one in mid-February.

Absence is more difficult to demonstrate and, in some cases, it may be prudent to assume that a suitable site underground in good habitat and close to other known roost sites is used by bats.

Automated/static surveys for winter activity within structures with a moderate to high likelihood of bats being present should be undertaken for a minimum of two weeks in each month from December to February.

### 5.3.8 Weather conditions

As the highest numbers of bats are found in the coldest conditions, it is advisable for surveys to be carried out when the weather is at its coldest.

### 5.3.9 Next steps

**Where bat hibernation roosts are likely to be impacted by proposed activities, it will be necessary to carry out an impact assessment and design an appropriate mitigation strategy with habitat enhancements for bats where appropriate.**

[44] http://www.bats.org.uk/pages/about_bats-white-nose_syndrome-586.html

Chapter 6

# Bat roost inspection surveys – trees

## 6.1 Introduction

This chapter provides information on carrying out inspection surveys for bat roosts in trees. Alternative sources of information are BS 8596:2015 Surveying for bats in trees and woodland (BSI, 2015) and the Bat Tree Habitat Key (Andrews, 2013).

These surveys may be required where development proposals include tree felling or lopping where bats or their roosts could be *directly* impacted if present.

Some of these surveys may also be needed where bats roosting in a tree could be *indirectly* impacted by development activities such as lighting or removal of vegetation.

The above principles apply regardless of the size of the development.

Surveying trees for bat roosts can be more challenging than surveying buildings because many species that use trees for roosts are known to exhibit roost switching behaviour, including barbastelle, Bechstein's bat, Daubenton's bat, Natterer's bat, Leisler's bat, noctule, common pipistrelle and brown long-eared bat (Harris and Yalden, 2008, Dietz *et al.*, 2011). Some UK examples are as follows: Smith and Racey (2008) observed roost switching in Natterer's bat on average every 3 days; and Waters *et al.* (1999) observed roost switching in Leisler's bat between every 2 and 10 days. Frequent roost switching has also been observed in barbastelle (Billington, 2003; Greenaway, 2001; Zeale, 2011) and Bechstein's (Palmer, 2013), two of our rarest species.

Additional difficulties inherent in finding tree-roosting bats are as follows: droppings do not persist in trees in the same way as they do in buildings; some tree-roosting bats echolocate very quietly (and sometimes not at all) and are therefore difficult to detect using bat detectors; some tree-roosting bats emerge from their roosts very late and return very early; and emergence surveys are often constrained due to the height of tree roosts above ground level and restricted observation due to foliage or lack of light under the canopy. The chances of discovering a roost, even if one is present, are relatively low. However, some of our rarest species are heavily reliant on tree roosts.

**Due to these limitations and from what is known about the ecology of tree-roosting bats, it is arguable that all trees with bat roosting potential should be considered part of a resource that will be used at one time or another by tree-roosting bats in order to determine the extent of impacts. Survey work on individual trees may confirm presence but is unlikely to conclusively confirm absence.** Precautionary measures are likely to still be essential during works even where surveys have not identified occupancy.

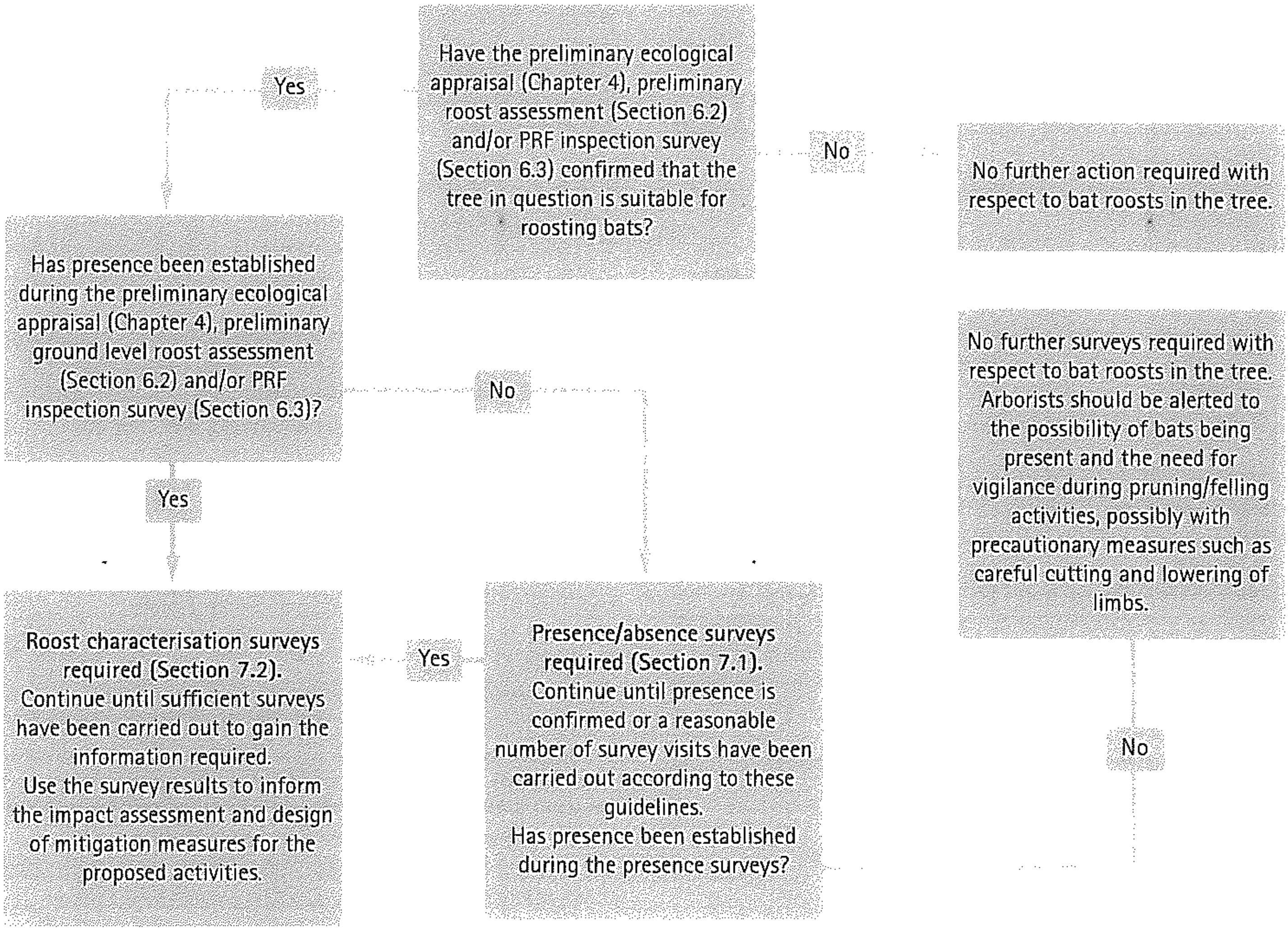
Where survey work is required, it should be designed to answer specific questions, such as:

- Are actual or potential bat roosts present (and where are they)?
- Which bat species use the site for roosting?
- How many bats are these roosts likely to support?
- What is the current arrangement of vegetation and lighting in relation to the access points?
- At what times of the year are bats present? How does use change seasonally?
- What types of bat roost are present, e.g. day, night, feeding, transitional/occasional, maternity, hibernation, satellite (see Section 3.3).

Answering some or all of these questions allows an ecologist to carry out an impact assessment and design a mitigation, enhancement and monitoring strategy, where relevant.

Roost surveys of trees generally take a staged approach, with the first step being a **preliminary ground level roost assessment** (possibly preceded or combined with a preliminary ecological appraisal; see Chapter 4), which may be followed up by **PRF inspection, presence/absence** and/or **roost characterisation surveys**. The latter two survey types are covered in Chapter 7, which also covers structures. Survey design should be iterative; each stage informing the next, as per the flow chart provided in Figure 6.1. The effectiveness of the surveys should be considered at each stage.

**Figure 6.1 Flow chart illustrating the process used to establish which types of survey are necessary for roosts in trees.**




## 6.2 Preliminary ground level roost assessment – trees

### 6.2.1 Description and aims

A **preliminary ground level roost assessment** of a tree is a detailed inspection of the exterior of the tree from ground level to look for features that bats could use for roosting (PRFs). The aim of this survey is to determine the actual or potential presence of bats and the need for further survey and/or mitigation.

### 6.2.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 6.2.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. A preliminary ground level roost assessment of trees is unlikely to result in disturbance to bats unless the ecologist intends to investigate low-level PRFs in trees with a torch or endoscope. If disturbance to bats is a possibility, then a survey licence is required.

### 6.2.4 Methods

The method involves a detailed inspection of the tree from ground level to compile information about the tree, PRFs (or lack of), and evidence of bats. Sufficient time should be allowed to complete the inspection during daylight hours. Poor light conditions can mean that PRFs are missed in trees. The inspection should be carried out systematically and consistently around all parts of the tree (from all angles and from both close to the trunk and further away) and the results recorded in a standard format. High-level PRFs can be identified by shining bright torches on cavities and shaded areas of the branches and using binoculars can help to focus in more detail.

All trees surveyed should be numbered and marked on a map or plan of the site (in some situations even trees with no PRFs should be mapped as a record). Information collected about the tree should at least include the location (grid reference) and tree species. Diameter at breast height can also be measured using a specialist tree tape (logger's tape) or number of stems can be recorded if the tree has been coppiced. This information will enable ecologists to locate the tree on subsequent visits. It is often difficult to find trees in a group or in woodland on a second survey visit and therefore marking individual trees with a tag or some tape may be essential. The permission of the landowner should be sought for this.

PRFs that may be used by bats include:

- woodpecker holes;
- rot holes;
- hazard beams;

- other vertical or horizontal cracks and splits (such as frost-cracks) in stems or branches;
- partially detached platey bark;
- knot holes arising from naturally shed branches, or branches previously pruned back to the branch collar;
- man-made holes (e.g. cavities that have developed from flush cuts) or cavities created by branches tearing out from parent stems;
- cankers (caused by localised bark death) in which cavities have developed;
- other hollows or cavities, including butt-rots;
- double-leaders forming compression forks with included bark and potential cavities;
- gaps between overlapping stems or branches;
- partially detached ivy with stem diameters in excess of 50mm;
- bat, bird or dormouse boxes.

Andrews (2013) provides more information on specific arboricultural terms for these features and how/why they form in trees.

Information collected about PRFs should include a description, the height of the feature above ground level, the orientation of the feature in relation to the trunk and the orientation of the access to the feature. This information will enable ecologists to locate the PRF on subsequent visits.

Signs of a bat roost, besides the actual presence of bats, include:
- bat droppings in, around or below a PRF;
- odour emanating from a PRF;
- audible squeaking at dusk or in warm weather;
- staining below the PRF.

Some of these signs (odour, squeaking) may be the result of other animals such as birds or squirrels and staining may be the result of wet rot, which would preclude roost presence. Bats or bat droppings are the only truly conclusive evidence of a roost but many bat roosts have no external signs.

During a preliminary ground level roost assessment of trees a more precise assessment of suitability is made than during a preliminary ecological appraisal (see Table 4.1 on page 35 for definitions of suitability). However, the evaluation at this stage is still relatively basic because it is not possible to inspect PRFs (except those at ground level) more closely to ascertain their true potential for supporting roosting bats. A tree should be categorised according to the highest suitability PRF present.

### 6.2.5 Complementary methods

See Section 5.2.5 and Appendix 4 regarding the collection of droppings to enable identification using DNA analysis. The main constraint with respect to collecting droppings from trees is their quality, because droppings can rapidly decay in trees.

### 6.2.6 Timing

Preliminary ground level roost assessments of trees are best carried out in winter (after the leaves have fallen and before new ones replace them – around December to March). If it is necessary to carry out these surveys when the leaves are on the trees, then it may not be possible to see all PRFs and surveys may need to be repeated in the winter months or a more thorough PRF inspection survey carried out to detect all PRFs, as far as possible. When these surveys are carried out in the summer, it may be possible to hear bats making audible social calls (or non-audible calls, using a bat detector) from roosts in trees. An example is available on the CD-ROM that accompanies *Woodland Management for Bats* (FC England *et al.*, 2005).

### 6.2.7 Survey effort

The time needed for a preliminary ground level roost assessment will vary according to the size of the trees, the number of PRFs and the number of ecologists deployed.

As a guide, it may be possible for a single ecologist to inspect 20–30 trees in a day if those trees are large, veteran oaks with multiple PRFs. It may, however, be possible to inspect double the number or more if the trees are smaller and with less potential for roosting bats.

### 6.2.8 Weather conditions

Preliminary ground level roost assessments for trees are best carried out in bright, dry and calm weather because these conditions maximise the chances of seeing PRFs.

### 6.2.9 Next steps

**Where suitable roosting habitat (moderate or high suitability; see Table 4.1 on page 35) or evidence of bats is found during a preliminary ground level roost assessment then further surveys (such as PRF inspection surveys (Section 6.3), presence/absence surveys (Section 7.1) or roost characterisation surveys (Section 7.2)) are likely to be necessary if impacts on the roosting habitat or the bats using it are predicted.** The ecologist should consider the further surveys needed (if any), their logistics (resources, emergence survey locations, timings), and any potential health and safety hazards reported.

**If no or low suitability PRFs for bats are found (using the definitions in Table 4.1) then further surveys are not necessary**. In this scenario, it is necessary to document how this decision has been reached; photographs and detailed descriptions should be made available as evidence of a robust survey and assessment. Where there are low suitability PRFs, precautionary measures may be appropriate during felling or pruning activities.

If ground level surveys are inconclusive, and PRFs could be present at height, it may still be necessary to carry out further surveys (see Section 6.3).

## 6.3 PRF inspection surveys – trees

### 6.3.1 Description and aims

A **PRF inspection survey** involves the use of tree-climbing or access equipment such as cherry pickers, MEWPs or scaffold towers to gain access to PRFs to assess in more detail their likely suitability for bats and to look for evidence of bats such as live or dead bats, droppings, staining or odour. These surveys are valuable to prevent unnecessary emergence/dawn work where features appear to be of high suitability from the ground but are actually of limited or no suitability. Tree climbing is often the most effective way to access all features but may be constrained by health and safety issues (e.g. trees may be unsafe to climb) and therefore it may be more appropriate to use alternative access equipment or skip to presence/absence surveys (see Section 7.1).

The aim of this survey is to reclassify PRFs and determine the presence/absence of bats at the time of the survey and the need for further survey and/or mitigation.

### 6.3.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 6.3.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. A PRF inspection survey to look for bats could cause disturbance and therefore it is good practice for ecologists to hold a survey licence. Where bats are present, this allows immediate identification, reducing the risk that the bats will remain unidentified if not present on a subsequent visit.

In order to carry out PRF inspection surveys using tree climbing, ecologists should be trained, qualified and experienced in tree climbing and aerial rescue and only work in pairs. Skills should be kept up-to-date through regular use and refresher courses should be considered for those who use these skills only infrequently. In this scenario, it may be appropriate for an ecologist to team up with an arborist to ensure that surveys are carried out as safely and efficiently as possible.

Owner- or operator-specific training may also be required when ecologists employ cherry pickers, MEWPs or scaffold platforms to access PRFs for inspection.

### 6.3.4 Methods

The method involves accessing PRFs using a harness and ropes (or other access equipment) to carry out a detailed internal inspection using torches, mirrors and endoscopes to compile information on the dimensions and protection from the elements and to search for evidence of bats. PRFs that appear to be of high suitability from the ground may only be of low suitability because, for example, they are filled with rainwater. Close inspection of features can be extremely useful because it facilitates a much more reliable assessment of suitability and provides an opportunity for bats and bat droppings to be found if they are present.

Sufficient time should be allowed to complete PRF inspection surveys during daylight hours. Poor light conditions could jeopardise safety and cause disturbance to bats at emergence time. The inspection should be carried out systematically and consistently around all parts of the tree and the results recorded in a standard format.

During a PRF inspection survey, the ecologist should collect information about the dimensions of features as this information may be required at a later stage. The ecologist should also review the evaluation that was made during the preliminary ground level roost assessment (see Section 6.2) according to the definitions provided in Table 4.1 on page 35. The evaluation at this stage is more accurate due to PRFs being more closely inspected. A tree should be classified according to the highest suitability PRF identified during the tree climbing survey.

### 6.3.5 Complementary methods

See Section 5.2.5 and Appendix 4 regarding the collection of droppings to enable identification using DNA analysis. The main constraint with respect to collecting droppings from trees is their quality, because droppings can rapidly decay in trees.

### 6.3.6 Alternative methods

Where there are large numbers of trees, the efficiency and efficacy of PRF inspection and other techniques should be evaluated and alternative methods considered. In situations where there are a lot of trees to survey, such as in woodland, it may be more effective to consider advanced licence bat survey techniques (ALBST) such as trapping and radio tracking to locate tree roosts. Such methods are invasive and can be expensive, therefore the decision to use them should be led by the potential impacts of the proposals and thus the requirement to collect the data. ALBST are covered in Chapter 9.

### 6.3.7 Timing

PRF inspection surveys can be carried out at any time of year, although the likelihood of discovering evidence of bats at different times should be considered.

Tree climbing surveys should also consider other protected species such as birds and red squirrels and, if present, the timing of surveys may need to be adjusted accordingly or a specific licence may be required.

### 6.3.8 Survey effort

The time needed for PRF inspection surveys will vary according to the size of the trees and the number of PRFs. For tree climbing, time taken often depends on experience. Efficiency can be gained by teaming up ecologists with arborists, who are often more experienced in accessing difficult areas of trees. For PRF inspection surveys using access equipment such as cherry pickers, the time required is likely to depend more on ground conditions and barriers to movement such as hedgerows.

As a guide, it may be possible for an ecologist to inspect only two to four trees in one day if those trees are large, veteran oaks with multiple PRFs. It may, however, be possible to inspect two or three times this many if the trees are smaller and with less potential for roosting bats.

Andrews and Gardener (2015) presented a summary of evidence and an encounter probability model for PRF inspections for tree-roosting bats. The model suggests that a very high number of visits is required to be sure of encountering bats; likely survey 'success' needs to be taken into account when designing surveys to capture evidence of bats and interpreting their findings.

### 6.3.9 Weather conditions

Tree climbing surveys are best carried out in dry and calm weather for safety reasons.

### 6.3.10 Next steps

**Where a PRF has been verified as moderate or high suitability for bats or evidence of bats is found, further surveys are likely to be necessary if impacts on the PRF or**

**the bats using it are predicted (Section 7.1 and 7.2).** These are particularly important where features could not be inspected at all; could not be inspected in their entirety because they were too extensive; or where evidence of bats may have been removed by the weather or invertebrates resident in the PRF. The ecologist should consider the further surveys needed (if any), their logistics (resources, emergence survey locations, timings), and any potential health and safety hazards reported.

**If no or only low suitability PRFs for bats are found then further surveys are not necessary.** In this scenario, it is necessary to document how this decision has been reached: photographs and detailed descriptions should be provided to the client as evidence that an adequate survey has been carried out and the conclusions are reasonable. Where there are low suitability PRFs precautionary measures may be appropriate during felling or pruning activities.

Chapter 7

# Emergence/re-entry surveys – structures and trees

## 7.1 Presence/absence surveys

### 7.1.1 Description and aims

**Presence/absence surveys** include dusk and/or dawn visits to watch, listen for and record bats exiting or entering bat roosts. If the presence of bats has been confirmed, then roost characterisation surveys (see Section 7.2) may be required (depending on how much information on species, numbers, access points, roosting locations, timing of use and type of roost has already been collected), although other features, structures or trees on site may still require presence/absence surveys.

Presence/absence surveys would be needed if:

- the preliminary roost assessment (structures and trees) has not ruled out the reasonable likelihood of a roost being present (because there are locations with potential for bats to roost undetected in concealed cracks, crevices or voids), but no definitive evidence of the presence of bat roosts has been recorded;
- the PRF inspection survey (trees) has identified moderate and high suitability PRFs for bats but no definitive evidence of the presence of bat roosts has been recorded;
- a comprehensive inspection survey is not possible because of restricted access, but there are features with a reasonable likelihood of supporting bats; and/or
- there is a risk that evidence of bat use may have been removed by weather or human activities.

The aim of this survey is to determine the presence or absence of bats at the time of the survey and the need for further survey and/or mitigation.

The additional limitations of tree surveys (in comparison to surveys of structures) are highlighted in Section 6.1.

### 7.1.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 7.1.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. Presence/absence surveys are unlikely to disturb bats if carried out correctly; however, it is good practice for these surveys to be designed and carried out, or at least led, by licensed surveyors who have gone through a period of training and evaluation.

### 7.1.4 Methods

The method involves ecologists visiting at dusk or dawn to listen/record (using a bat detector) and watch for bats emerging or returning to roosts and compile information on species, numbers, access points and roosting locations. This should be informed by the preliminary roost assessment (see Sections 5.2 and 6.2), which identified potential roosting and access points, and by the PRF inspection survey for trees (see Section 6.3), which clarified the potential suitability of different PRFs to bats. These places should be the focus of the survey and their number and arrangement should inform the number and arrangement of surveyors required to complete the survey (although ecologists should be aware that bats may emerge in unexpected places). Ecologists should be adequately briefed about the exact area they are expected to observe for emerging or returning bats and the areas their colleagues are observing to avoid double-counting. Radio contact can help ecologists to communicate easily and quickly about their observations.

Sufficient surveyor coverage of a structure is required and it is important that enough ecologists are used to thoroughly observe all potential access points, ideally during a single survey, and this should be checked by those assessing surveys and reports.

Generally, one ecologist can only observe two sides of a simple structure, from the corner, and their ability to do so reduces as the complexity and size (i.e. length/width) of the structure increases or where observation is obscured by a tall hedge, wall or other obstacle. More complex structures or multiple structures require more ecologists, particularly if there are many potential access points, as all areas with potential should be covered. If fewer ecologists are available it may be necessary to visit the site (standing at different locations each time) over several consecutive nights (collectively considered to be one survey visit) to cover all areas.

Ecologists should consider whether it will be possible to watch all the PRFs on a tree with a single ecologist and use additional ecologists where necessary, for example where PRFs are on different aspects of a tree or one or more PRFs are obscured by foliage. It is sometimes not possible to see all PRFs from the ground so this should also be taken into account.

It may be possible to use fewer ecologists to watch for bats exiting; for example, a block of buildings or a woodland as a whole unit, but this would only identify that roosts were present within the block/woodland and would not identify individual buildings, trees or roosts. The choice of method depends on the amount of detail required to meet the survey aims.

Surveyors should be stationary to avoid bats being missed. One or two ecologists walking around a large site are unlikely to pick up individual bats or small roosts and could even miss larger roosts and is not appropriate.

Ecologists should concentrate and maintain visual contact with the relevant access points throughout (this can be facilitated by using a voice recorder) because single or small numbers of bats can emerge very quickly and are difficult to observe, particularly as light levels decrease at dusk (and they do not always echolocate). Where possible, ecologists should stand close enough to the relevant access points to be able to identify late-emerging, quiet-calling bat species (see Section 3.9). Some species are only detectable to a few metres and emerge in darkness (a torch should not be used). Dawn surveys may be more effective in this situation (and where there are only small roosts) because when bats return to the roost at dawn they often fly around outside, and may repeatedly land on roost access points prior to entering, whereas at dusk they often emerge and immediately fly away. Dawn surveys can be particularly useful for trees.

In some situations, for example with large open barn doors, it may be more effective for the ecologist to stand inside the doorway looking out to observe emerging bats against the lighter night sky rather than to stand outside the doorway looking into darkness.

If bats are observed emerging from structures, this does not necessarily mean they are roosting in the same location as the exit point; it may be necessary to identify roosting locations separately. Sometimes this can be established during the preliminary roost assessment. Survey design should be iterative, each survey informed by the previous one.

The results of the surveys should be recorded in a standard format using a pre-designed survey form.

### 7.1.5 Complementary methods

Night-vision scopes or infrared or thermal imaging cameras can increase precision in presence/absence surveys because bats are less likely to be missed if the camera is pointed at the relevant access point. This can be particularly important where there is potential for late-emerging species (see Section 3.9) and in dark conditions (for example, under the tree canopy and among fluttering foliage). Where footage is recorded, this can be analysed afterwards. However, the limited field of view offered by many systems should be considered if multiple exit points need to be observed. Infrared systems also require a separate source of true infrared illumination (not a red light filter) to be effective. While such equipment is very useful as a complementary technique, it should not be used to replace surveyors to any significant degree; the majority of any site should be observed by surveyors.

Deploying automated/static bat detectors inside a structure can be particularly useful in gaining information about late-emerging species that often fly around inside the roost prior to emergence. Caution should be exercised in using automated/static detectors for this purpose, however, because sometimes they can detect bats flying outside a structure, not just those flying inside.

### 7.1.6 Alternative methods

See Section 6.3.6 for alternative methods to detect the presence of bats in trees.

### 7.1.7 Timing

Recorded bat activity is dependent on the prevailing conditions at the time of the survey, which vary temporally (through the night, between nights, through the seasons and between years) and spatially (dependent on latitude and longitude).

Bat activity is also determined by what the bats are doing at different times of the year (although this is also dependent in part on prevailing conditions); the bat life cycle is given in Section 3.2.

The bat active period is generally considered to be between April and October inclusive (although the season is likely to be shorter in more northerly latitudes). However, because bats wake up during mild conditions in the winter to drink, feed and change roost, bat activity can also be recorded during the winter months (winter hibernation surveys of structures are covered in Section 5.3).

In general:

- April surveys may detect transitional roosts.
- May to August surveys may detect maternity colonies and males/non-breeding females in summer roosts.
- August is particularly good for maximum counts of both adults and juveniles and can be useful to observe roost re-entry because the young bats are inexperienced at flying and are often easy to observe as they try to enter the roost.
- August to October surveys may detect mating bats.
- September and October surveys may detect transitional roosts used after bats have dispersed from maternity colonies but before they go into hibernacula (although October may be less suitable for surveys in more northerly latitudes).

It is important to stress that prevailing conditions and local trends in bat activity (for example, when were the young born in the year in question?) should be considered and recorded to provide context to survey results.

Surveys should be designed around the information that is required to achieve the survey aims. Recommended timings for surveys are given in Table 7.1 below. This should be adjusted (earlier or later) if necessary by the ecologist, bearing in mind the site-specific circumstances, although this should be fully justified in the survey report.

Please note that these are the timings recommended for presence/absence surveys. Some roost characterisation surveys (see Section 7.2.7) may be appropriate in April (to identify transitional roosts) and October (to identify transitional and mating roosts) depending on the findings of previous surveys, the weather and the location (although please note that October surveys are not considered appropriate in Scotland).

**Table 7.1 Recommended timings for presence/absence surveys to give confidence in a negative result for structures (also recommended for trees but unlikely to give confidence in a negative result).**

| Low roost suitability | Moderate roost suitability | High roost suitability |
|---|---|---|
| May to August (structures)<br><br>No further surveys required (trees) | May to September[a] with at least one of surveys between May and August[b] | May to September[a] with at least two of surveys between May and August[b] |

[a] September surveys are both weather- and location-dependent. Conditions may become more unsuitable in these months, particularly in more northerly latitudes, which may reduce the length of the survey season.
[b] Multiple survey visits should be spread out to sample as much of the recommended survey period as possible; it is recommended that surveys are spaced at least two weeks apart, preferably more, unless there are specific ecological reasons for the surveys to be closer together (for example, a more accurate count of a maternity colony is required but it is likely that the colony will soon disperse). If there is potential for a maternity colony then consideration should be given to detectability. A survey on 31 August followed by a mid-September survey is unlikely to pick up a maternity colony. An ecologist should use their professional judgement to design the most appropriate survey regime.

Different species vary in the time they tend to emerge and return to the roost according to their flight and predator avoidance capabilities. *Pipistrellus* species and noctule often emerge early and return late; brown long-eared bat and Natterer's bat often emerge late and return early (see Section 3.5).

Table 7.2 gives recommended timings for dusk and dawn surveys. These are times that ecologists should be in place.

**Table 7.2 Recommended timings for presence/absence surveys.**

| Survey type | Start time | End time |
|---|---|---|
| Dusk emergence | 15 minutes before sunset[a] | 1.5–2 hours after sunset[b] |
| Dawn re-entry | 1.5–2 hours before sunrise[b] | 15 minutes after sunrise[c] |

[a] Survey start time should be adjusted on subsequent surveys if bats are recorded already in flight at 15 minutes before sunset on the first survey (or, if only one survey had been planned, this survey may then need to be repeated).
[b] The possibility of late-emerging and early-returning species should be considered in setting times for surveys (see Section 3.5).
[c] If bats are still in flight 15 minutes after sunrise then ecologists should remain in position until all the bats have entered their roosts.

Although these time periods mean that some of the survey is in complete darkness, ecologists can still listen out for and record activity and may be alerted to the possible presence of a roost of late-emerging species so that survey methods can be adjusted either at the time or on a subsequent survey. Adjustments could include changing to a dawn survey; using night-vision scopes or infrared or thermal imaging cameras at dusk or dawn; or deploying an automated/static detector inside a structure.

Other considerations in terms of timing are as follows:

- if a roost emergence point is not lit by the setting sun, it is likely to be darker and bats may emerge earlier and return later;
- if bats have vegetation cover close to the roost they may emerge earlier and return later because the vegetation offers protection;
- if there have been periods of prolonged bad weather bats may adjust their behaviour to increase foraging times by emerging earlier or returning later;
- poor weather conditions may cause bats to alter their emergence/return times (see Section 2.6.1); and
- if the roost is very large some of the bats may emerge earlier and return later.

Timings may be adjusted (earlier or later) if necessary by the ecologist, bearing in mind the site-specific circumstances, although this should be fully justified in the survey report.

### 7.1.8 Survey effort

More ecologists with more equipment (if used correctly) in more seasons and under the right weather conditions generally increases the likelihood of discovering bats. However, surveys should always be proportionate to the circumstances, which can only be assessed using professional judgement.

Table 7.3 provides the minimum recommended numbers of survey visits to give confidence in a negative result for structures. Confidence in a negative result is not possible for trees due to limitations outlined in Section 6.1. The number of visits could be adjusted (up or down) if necessary by the ecologist, bearing in mind the site-specific circumstances, although this should be fully justified in the survey report.

**Table 7.3 Recommended minimum number of survey visits for presence/absence surveys to give confidence in a negative result for structures (also recommended for trees but unlikely to give confidence in a negative result).**

| Low roost suitability | Moderate roost suitability | High roost suitability |
|---|---|---|
| One survey visit. One dusk emergence or dawn re-entry survey[a] (structures).<br><br>No further surveys required (trees). | Two separate survey visits. One dusk emergence and a separate dawn re-entry survey.[b] | Three separate survey visits. At least one dusk emergence and a separate dawn re-entry survey. The third visit could be either dusk or dawn.[b] |

[a] Structures that have been categorised as low potential can be problematic and the number of surveys required should be judged on a case-by-case basis (see Section 5.2.9). If there is a possibility that quiet calling, late-emerging species are present then a dawn survey may be more appropriate, providing weather conditions are suitable. In some cases, more than one survey may be needed, particularly where there are several buildings in this category.

[b] Multiple survey visits should be spread out to sample as much of the recommended survey period (see Table 7.1) as possible; it is recommended that surveys are spaced at least two weeks apart, preferably more. A dawn survey immediately after a dusk one is considered only one visit.

Some situations may justify a dawn survey being carried out the morning after a dusk survey. For example, if it is not clear exactly where a bat emerged from or even that the bat actually emerged, a dawn survey can be used to clarify the situation. An ecologist will be able to adjust his/her position for the dawn survey to get a better view. This may be important if the roost is thought to be transitional because the bat may have moved on by the next survey visit. If the dusk survey is conclusive, then there is less value in carrying out a dawn survey immediately after. A dusk survey immediately followed by a dawn survey should be considered to be only one survey visit because this is insufficient time for roosting behaviour to have significantly changed.

Numbers of surveys may need to be increased from those recommended in Table 7.3 where thorough internal inspections have not been possible; the number should be decided using professional judgement and rationale reported. Internal inspections (of structures and PRFs) can provide historical evidence of bat presence whereas emergence and dawn surveys only provide information about bat presence or absence at the time of the survey.

### 7.1.9 Weather conditions

Please refer to Section 2.6.1 for guidance on weather.

### 7.1.10 Next steps

If presence of a bat roost(s) is established, the next stage of the process is to carry out roost characterisation surveys (see Section 7.2 – depending on how much information on species, numbers, access points, roosting locations, timing of use and type of roost has already been collected), although it may be necessary to continue with presence/absence surveys of other parts of the structure, tree or site.

In structures, where likely absence has been adequately established, then no further action is required in relation to bats. However, it may be appropriate for contractors to be briefed about the risk of discovering bats unexpectedly during works and the need to stop work in this scenario.

In trees, it is very difficult to have confidence that roosts are absent (see Section 6.1) and therefore, even where no bats are found, it may still be necessary to apply precautionary measures when carrying out tree felling and pruning activities.

## 7.2 Roost characterisation surveys

### 7.2.1 Description and aims

When presence is established, this should trigger **roost characterisation surveys** unless sufficient information has already been collected to inform the impact assessment and design of mitigation measures. Roost characterisation surveys include emergence/re-entry surveys. They also include the collection of information about the physical characteristics of the roost and surrounding area.

The aim of these surveys is to answer the questions outlined in Sections 5.1 and 6.1, and to ascertain the features and characteristics of the roost (for example size, perching points, aspect, orientation, temperature, humidity, lighting) and the surrounding area (for example proximity of vegetation to exit points, availability of foraging areas locally) that are important.

All of this information can then be used to assess the potential impacts of the proposed development activity and design suitable mitigation and monitoring strategies. For example, information on roost characteristics may be required to inform the construction of a like-for-like replacement roost where the original roost will be lost. This information is essential when applying for planning permission or an EPS licence.

The additional limitations of tree surveys (in comparison to surveys of structures) are highlighted in Section 6.1.

### 7.2.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 7.2.3 Expertise and licences

The expertise and licences required are the same for both presence/absence surveys and roost characterisation surveys (see Section 7.1.3).

### 7.2.4 Methods

The method used is the same for both presence/absence surveys and roost characterisation surveys (see Section 7.1.4).

Some bat species will not waste energy echolocating in higher light levels, which means other methods should be used to gain the species identification information required; for example, DNA analysis of droppings (see Section 5.2.5 and Appendix 4) or handling of bats (see Section 7.2.5). Visual cues such as behaviour, size, wing shape and ear shape may also contribute to identification but in most cases these cannot be used in isolation.

The collation of information about the physical characteristics of the roost and surrounding area is discussed below.

❍ **Size and nature of roost**

In structures, the size of the roost, including the presence and location of timber joints and other features supporting roosts, should be documented if it is likely that a replacement roost will be required. The size and nature of the internal space may be important to bats that fly around inside prior to emerging, most notably *Plecotus*, *Rhinolophus* and some *Myotis* species. The number and location of all access points (and their dimensions, which can be important for some species) should also be documented.

In trees, the dimensions of the roost feature should have been documented during the PRF inspection survey (see Section 6.3) if it has been possible to carry one out.

❍ **Roosting surfaces**

In structures, the availability of appropriate roosting surfaces (e.g. natural materials such as wood) is a key measure of the ecological functionality of a site, and should be recorded if it is likely that the roost will need to be replaced.

❍ **Aspect and orientation**

The aspect, orientation and shading of the roost and associated access points should be carefully documented, again so that this can be replicated in a replacement roost if necessary. Aspect and orientation affect how the roost is heated by the sun, although in structures heating may also result from man-made features such as boilers. If this is the case, it should also be recorded.

❍ **Temperature and humidity**

Williams (2010) and Gunnell *et al.* (2013) state that one of the factors making structures suitable for roosts is their ability to provide a stable microclimate and that temperature plays a key role in roosting ecology and selection. Where proposals will result in the loss of a maternity or hibernation roost, the temperature and humidity inside and outside the roost should be monitored using data loggers to understand how conditions fluctuate in relation to ambient temperatures throughout the season the roost is used (although this may be constrained by limited access to the areas bats are actually using). In structures that are used by bats at different times of the year, it may be necessary to collect data during more than one season. It can be the damping of temperature variation, rather than absolute temperatures, that make a roost suitable for bats. Collecting data inside and outside the roost will help to understand this and replicate conditions, where possible, in replacement roosts. Different conditions are likely to suit different species (see, for example, Boonman, 2000; Smith and Racey, 2005; Davidson-Watts and Jones, 2006).

❍ **Lighting**

Current lighting levels and locations should be noted to provide a comparison with new lighting proposals. Even one change such as an outside security light can have an impact and lighting needs to be considered in relation to current and proposed new bat access points. In cases where no significant change is proposed, it may not be necessary to measure the light levels at all, but current lighting fixtures should be plotted.

❍ **Habitat**

Vegetation in close proximity to a roost can be extremely important for some species of bat that seek cover from predators and the weather immediately after emerging. It also provides structure for acoustic orientation and navigation and opportunities for foraging. Features likely to be important to bats should be noted so that these can be retained or replicated post-development as necessary. The importance of different habitat features vary from species to species (see, for example, Davidson-Watts *et al.*, 2006; Entwistle *et al.*, 1997).

### 7.2.5 Complementary methods

The complementary methods are the same for both presence/absence surveys and roost characterisation surveys (see Section 7.1.5).

It may also be possible to capture bats using a hand net in order to identify their species, gender and age during a roost characterisation survey. The correct licence (see Section 1.2.2), knowledge and skills (see Section 2.5.1) should be in place to carry out this activity and sensitive times of year should be avoided (such as when bats are heavily pregnant or with dependent young).

### 7.2.6 Alternative methods

See Section 6.3.6 for alternative methods to detect the presence of bats in trees.

### 7.2.7 Timing

See Section 7.1.7; comments on timing are the same for both presence/absence surveys and roost characterisation surveys. It may be appropriate to carry out surveys in April and/or October depending on the need to characterise transitional roosts or mating roosts, the findings of previous surveys, the weather and the location (although please note that October surveys are not considered appropriate in Scotland).

### 7.2.8 Survey effort

Survey effort required to collect the relevant information that is needed for an impact assessment and the design of mitigation strategies is very much site-specific. Dusk and dawn surveys should be repeated until the information outlined in Sections 5.1 and 6.1 is reliably collected, although appropriate methods and equipment should be used to minimise the number of repeat visits required and effort should always be proportionate to impact.

If presence has been confirmed by droppings found during a preliminary roost assessment (Sections 5.2 and 6.2) but bats have not been detected during roost characterisation surveys, it may be necessary to carry out further surveys at alternative times of year.

### 7.2.9 Weather conditions

Please refer to Section 2.6 for guidance on weather.

### 7.2.10 Next steps

**Where bat roosts are likely to be impacted by proposed activities it will be necessary to carry out an impact assessment and design an appropriate mitigation and monitoring strategy with habitat enhancements for bats where appropriate. This information is essential to inform a planning application or EPS licence application to allow the proposed activities to proceed legally.**

Chapter 8

# Bat activity and back-tracking surveys

## 8.1 Introduction

This chapter provides information on carrying out bat detector surveys for bats. These bats may be commuting, foraging or exhibiting social behaviour (such as calling for mates during the mating season or swarming in the autumn). Acoustic surveys enable identification of species and provide an index of bat activity. Actual numbers of individuals can often not be established unless acoustic data is coupled with direct observations in the field by an ecologist, or through recordings made by an infrared or thermal-imaging camera.

These surveys may be required where development proposals are likely to impact on habitats suitable for bat commuting and foraging (see Section 2.2.2). Road and rail schemes can cause the specific impact of collision and it is good practice to carry out automated/static bat activity surveys of crossing points.

As with all surveys, survey design should be based around the questions that require answers. For the purposes of development and planning, the main questions with respect to bats in flight away from their roosts are generally as follows:

- Are bats present or absent?
- Which bat species use the site?
- What are the activity levels of bats on the site and can this tell us anything about the abundance (number) of bats using the site?
- What are bats using the site for?
- What is the temporal (both seasonally and in relation to time of night) and spatial distribution of recorded bat activity on site?
- Are peaks in bat activity associated with particular temporal and/or spatial locations, e.g. times of night or parts of the site?
- How are the habitats used on site connected to habitats in the surrounding area?

Answering some or all of these questions should allow an ecologist to carry out a robust impact assessment.

In order to answer these questions, bat activity surveys generally begin with the preliminary ecological appraisal, which includes a desk study and fieldwork (see Chapter 4). This provides existing data about bats in the area and identifies and assesses the suitability of habitats on site for bats. This information should be used to inform survey design, which should be iterative; each stage should inform the next.

The following sections describe **transect** and **automated/static bat activity surveys, back-tracking surveys** and **swarming surveys.**

## 8.2 Bat activity surveys – manual and automated/static

### 8.2.1 Description and aims

Manual bat activity **transect surveys** involve ecologists walking predetermined transect routes in order to observe, listen for and record bats in flight away from their roosts using hand-held bat detectors and recorders. **Automated/static activity surveys** involve bat detectors being deployed at fixed locations to record bat activity remotely. These are usually used in combination with transect surveys.

The aim of these surveys is to answer the questions posed in Section 8.1. The results of these surveys can then be used to inform the need for further surveys or to facilitate an impact assessment and the subsequent design of appropriate mitigation.

### 8.2.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 8.2.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. Activity surveys are unlikely to disturb bats if carried out correctly; however, it is good practice for these surveys to be designed and carried out, or at least led, by licensed surveyors who have gone through a period of training and evaluation.

### 8.2.4 Methods

#### 8.2.4.1 Transect surveys

Appropriate transect routes should be determined during the fieldwork carried out as part of the preliminary ecological appraisal (see Chapter 4). This survey should have identified the different habitats in the survey area that will be impacted by the proposed activities and may have assessed suitability (see Section 4.3.4). All habitats should be sampled but the habitats identified as having moderate or high suitability for bats are likely to be the main focus of the transect surveys.

The extent and arrangement of the different habitats on site should inform the number and arrangement of transects required to complete the survey. This is also influenced by ease of accessibility and navigation. Some habitat types (for example, wetlands or dense scrub/woodlands) may constrain transect surveys and increase the emphasis on collecting data from spot counts, timed searches (see Section 8.2.5) or automated/static surveys (see Section 8.2.4.2).

Ideally, ecologists should have the opportunity to walk transects during the daytime in order to avoid getting lost; to identify hedge or watercourse crossing points; and to identify any particular hazards. It is more appropriate for this work to be carried out in pairs; for ecologists to know where other colleagues will be on site; and for the method of communication to be identified. This may require two-way radios in the absence of mobile phone signal.

During transect surveys, an ecologist should walk at a fairly constant speed (so the sampling area is the same per unit time) along a planned route recording observations of bats such as number of bats, flight direction, flight height, behaviour (e.g. commuting or foraging – the latter can be identified through hearing feeding buzzes), appearance and relative speed. Much of this is qualitative information that cannot be recorded using the automated systems described in Section 8.2.4.2, although obviously constrained by light levels (more so in cluttered habitats). All echolocation calls should be recorded and subsequently analysed to species or genus (see Chapter 10) even if the ecologist has attempted to identify the species by ear in the field.

Technology is available to record each bat echolocation call and link it to a specific location (using GPS points) and time to enable the data to be easily mapped and presented in reports, although some ecologists still use paper recording forms to record time, location, species and behaviour.

Because an ecologist is only in one location at a given time, it is likely that bat activity will be missed. Repeating a short transect twice during the course of one evening, randomly varying the starting point through the season and/or supplementing transect surveys with automated/static detector surveys can help to overcome this limitation. Different methods facilitate different types of analysis. For example, randomising the start point across a suite of surveys facilitates the production of a kernel density plot of the activity along the transect (see Figure A7.6).

Ideally, all habitats represented on site should be sampled by transects during a single survey visit to allow a comparison of bat activity across the site. However, if few ecologists are available and the site is particularly large it may be necessary to visit the site (covering different transects each time) over several consecutive nights (collectively considered to be 'one survey visit') to cover all areas.

Transect surveys can be undertaken as:

- **dusk surveys only** – this is likely to be the most effective method in the spring and autumn when conditions are likely to deteriorate in the night and may cause bats to go back to their roosts and not emerge for a second time before dawn;

- **dusk and pre-dawn surveys with a break between the two** – this is a useful method if the conditions are appropriate for pre-dawn activity but long nights mean a dip in bat activity is experienced in the middle of the night;

- **dusk to pre-dawn surveys** – this is most useful on short summer nights when activity levels remain high, or where the aim is to record particular types of bat activity in the middle of the night such as mating or swarming along with dusk and dawn activity;

- **pre-dawn surveys only** – these may be used to record specific pre-dawn behaviours such as bats commuting back to a roost in a particular direction.

Where multiple transects are carried out at one site, they should all be approximately the same length. A good guide is 3–5km, but transects may be shorter than this depending on the site, ground conditions, whether or not stopping points are used and levels of bat activity.

**8.2.4.2 Static/automated surveys**

The use of static/automated detectors facilitates quantitative analysis of the data to supplement the often qualitative data collected during transect surveys. Some examples of strategies that can be used to identify bat detector locations are given below (please refer back to Section 2.2.6 on data analysis):

- **Random:** a random sampling strategy is a good method for not introducing bias (distortion) to the subsequent analyses. The survey area is divided up into a grid (10 × 10) of equal squares and rather than surveying all squares, 20 squares are chosen randomly from the 100. Each square is numbered from 1 to 100 and 20 numbers are generated randomly, between 1 and 100, and assigned to a square.

- **Systematic:** a systematic sampling strategy is a good method for not introducing bias (distortion) to the subsequent analyses. The survey area is divided up into a grid (10 × 10) of equal squares and rather than surveying all squares, every 5th square is chosen. Each square is numbered sequentially 1 to 100 and then squares 1, 5, 10, 15, 20, etc... are selected.

- **Judgemental:** sampling locations in the survey area are chosen subjectively. For example 20 sampling locations, using the example area above, are determined based on expert opinion (after the preliminary ecological appraisal; see Chapter 4) or historical information. The approach could be described as 'haphazard' and at the extreme can fall into 'convenience' (sampling at convenient places (or times)). Judgement sampling has inherent uncertainty, cannot be readily quantified and statistical methods cannot be applied. However, this approach may facilitate the chances of recording, for example, quieter calling bats (see Table 3.7 on page 31).

- **Stratified:** the survey area is divided unequally into sub-areas allowing a sub-area(s) of interest to be surveyed more intensively (identified during the preliminary ecological appraisal; see Chapter 4). Sub-areas can be analysed individually but care should be taken when looking at the area as a whole because a bias has been introduced; some areas have been surveyed more than others. One way of looking at the whole area, while surveying sub-areas more intensively, is to pair or group sample locations by factors and use the factors in the analysis. Factors are most useful when they are simple and easily defined:
  - Field 1 – Field 2 (adjacent to Field 1 and same area)
  - Hedgerow – Watercourse (same length)
  - Woodland – Open field (same area)

Random, systematic, judgemental and stratified sampling strategies also apply to the timing of surveys; the convention in bat surveying is to use timings that are systematic.

Ideally, the same model of automated/static bat detector should be used across the site, all detectors should be deployed with the same settings and all detectors should be subject to regular testing/calibration as appropriate to avoid the introduction of bias and to allow a meaningful comparison of the results.

The microphone should be positioned to maximise the amount of bat activity recorded – this requires knowledge and consideration of the directionality/sensitivity of the particular microphone used. The choice of microphone (uni- or omnidirectional) will depend on the objectives of the survey – both types have their uses.

Automated/static detectors may be deployed at varying heights depending on site and project-specific factors. It is not usually appropriate to deploy a detector on the ground because this will decrease the survey volume around the microphone. The microphone should be located so that the recording of ambient (e.g. wind, running water, rustling vegetation) or any other source of extraneous noise (e.g. electrical signals) is minimised. It is also important to consider whether solid objects nearby (e.g. vegetation, built structures, etc.) will impede the passage of sound to the microphone, and adjust its position accordingly. It may be appropriate to elevate the detector above the height of a hedgerow to enable recording on both sides or to deploy the detector just below or above the canopy of a woodland. It may also be necessary to fence the detector or have livestock moved from a field if surveying in open pasture is necessary.

Data from automated/static systems is limited because there is no observational context. One hundred bat passes could represent one bat passing 100 times or 100 bats each passing once. Reality is likely to be somewhere between these two extremes. In cases where high levels of activity are recorded it may therefore be necessary to contextualise the results (i.e. is it one bat or 100 bats) using a manual transect or spot count survey. These methods are complementary – each performs a different function.

Table 8.1 provides a summary of the comparative benefits and limitations of transect and automated/static surveys.

**Table 8.1 A summary of the comparative benefits and limitations of transect and automated/static surveys.**

| Survey type | Benefits | Limitations |
|---|---|---|
| Transect | • Bats can be counted<br>• Bat behaviour can be observed (more limited as light falls and in cluttered habitats) | • Snapshot of time only<br>• Ecologist is only in one location at any given time so could miss activity elsewhere<br>• Subjectivity of ecologist can limit consistency, repeatability and quantitative analysis<br>• Security of ecologists<br>• Difficult in some habitat types (e.g. dense woodland or scrub or open homogenous habitats)<br>• Labour-intensive fieldwork<br>• Can't be used at height |
| Automated/static | • Can be deployed for long periods to pick up variability in bat activity in the absence of ecologists<br>• Can be deployed in different locations simultaneously<br>• Large amounts of data generated<br>• More objective and therefore consistent, repeatable and allows quantitative analysis<br>• Full auto identification is possible with some models, although caution should be exercised in choice and accuracy of software and reliance on results<br>• Can be used very effectively for at-height surveys | • Bats cannot be counted<br>• Bat behaviour cannot be observed<br>• Large amounts of data generated, requiring significant storage capability<br>• Lots of data analysis<br>• Variability of weather over longer periods (though evens out over longer periods)<br>• Security of detectors<br>• Need to change memory cards and batteries |

The results of the surveys should be recorded in a standard format and survey design should be iterative, each survey informed by the previous one. This is particularly important for automated surveys, where issues with a particular site or piece of equipment that would not otherwise be apparent may need to be addressed.

## 8.2.5 Complementary/alternative methods

Transect surveys may be supplemented by **spot counts**, where ecologists remain stationary for short, set periods of time (3–5 minutes) at locations along a transect route selected to represent the different habitats in the survey area. It may be appropriate to only sample at the spot count locations (rather than also recording along the transect) in habitats that are difficult to navigate or walk such as dense woodlands, wetlands or on steep terrain. This can make hearing, observing and counting bats easier because there is no noise from footfall and the ecologist can focus on the survey rather than navigation and safety.

**Timed searches** allow ecologists to move freely around the survey area for a set amount of time responding to any visual or acoustic evidence of bats by moving towards it. Timed searches can be used to standardise survey methods for bat species that are difficult to detect, or if bats are spread over a wide area that cannot easily be sampled using transects or spot counts. Timed counts provide a simple and effective means of obtaining estimates of relative bat activity in homogeneous or difficult terrain such as mountains or wetland bogs; landscapes with few features (moor, open farmland); and areas where it is difficult to walk around (e.g. in dense woodland, built-up areas, railway marshalling yards, etc.). Large sites can be subdivided into smaller areas; a random sample of these can be selected for sampling or each can be sampled on a different night. Searching for a set amount of time introduces an element of standardisation that can be repeated in subsequent surveys.

**Vantage point** surveys can provide information about the behaviour of early-emerging and high-flying bats such as noctule. Ecologists are located at vantage points around the site, so that all areas are covered. They then observe and listen for bats in flight while light levels allow, before and after sunset or sunrise. These surveys can provide information about numbers of bats and direction of travel, which gives an indication of the direction of the roost and the direction of early evening foraging grounds.

Transect surveys have been carried out using bikes or cars to cover more ground (or boats in aquatic habitats). However, the limitations of these methods should be recognised. Car surveys are particularly constrained because they focus the survey only on roads/tracks and the noise and lights of the cars could disturb some bat species (particularly species that avoid light). Quieter-calling species can easily be missed so these methods should not be used in isolation.

It may be necessary to capture bats using mist nets or harp traps in order to identify their species, gender and age to supplement activity survey information. The correct licence, skills and experience should be in place to carry out this activity and sensitive times of year should be avoided (such as the maternity and hibernation seasons). More information on capture and handling is provided in Chapter 9.

### 8.2.6 Timing

Recorded bat activity is dependent on the prevailing conditions at the time of the survey, which vary temporally (through the night, between nights, through the seasons and between years) and spatially (dependent on latitude, longitude, altitude, habitat, etc.).

Bat activity is also determined by what the bats are doing at different times of the year (although this is also dependent on prevailing conditions); the bat life cycle is given in Section 3.2.

The UK bat active period is generally considered to be between April and October inclusive, although April, September and October surveys are both weather- and location-dependent (October surveys are generally not acceptable in Scotland). Conditions may become more unsuitable in these months, particularly in more northerly latitudes, which may reduce the length of the survey season. Some useful data may be collected outside these months or weather conditions during these months may render surveys ineffective – professional judgement should be applied to determine the most effective activity survey period for a particular project.

It may be appropriate to survey for bat activity in the winter, particularly if there are hibernation roosts in, or close to, the survey area. Foraging habitats close to hibernacula may be particularly important because during the winter bats need to minimise energy used to gain food during milder weather conditions. Automated/static surveys are likely to be the most efficient way of collecting data on winter bat activity.

Table 8.2 gives recommended timings for activity surveys.

**Table 8.2 Recommended start and end times for activity surveys.**

| Survey type | Start time | End time |
|---|---|---|
| Dusk survey – bat activity | Sunset[a] | 2–3 hours after sunset |
| Dusk survey – swarming | 2 hours after sunset | 5 hours after sunset |
| Dusk to pre-dawn survey | Sunset | Sunrise or later if bats still active |
| Pre-dawn survey | 2 hours before sunrise | Sunrise or later if bats still active |
| Automated bat detector survey | 30 minutes before sunset | 30 minutes after sunrise |

[a] Adjust to earlier if in darker habitats such as woodland or if data justifies (e.g. if bats are already out by sunset on previous surveys or automated detectors show pre-sunset activity).

Timings may be adjusted (earlier or later) if necessary by the ecologist, bearing in mind the site-specific circumstances, although this should be fully justified in the survey report.

### 8.2.7 Survey effort

When planning surveys it is important to take a proportional approach. The number of transects, automated/static surveys and repeat visits decided upon should be proportional to the factors described in Section 2.2.5. To briefly recap, with particular reference to activity surveys, these are:

- likelihood of bats being present;
- likely species concerned;
- numbers of individuals;
- type of habitat affected;
- predicted impacts of the proposed development on bats;
- type and scale of proposed development.

An activity survey should provide a representative sample of the bat activity in all habitats present at the proposed development site (see Section 8.2.4.1). Sampling should be designed to provide a sufficient amount of data to assess the potential impacts of the development on bats.

Bat activity is inherently variable from night to night, with this variability not explained by weather conditions alone (Scott and Altringham, 2014), and so multiple consecutive nights of survey with automated systems are recommended.

Table 8.3 gives guidelines on the number of bat activity surveys recommended to achieve a reasonable survey effort on sites with low, moderate and high-quality habitat for bats (as defined during the preliminary ecological appraisal fieldwork; see Table 4.1 on page 35). Please note that the elements outlined in Section 2.2 should be considered alongside habitat suitability in designing surveys. In particular, the potential impacts of the proposals (Section 2.2.2) and proportionality (Section 2.2.5).

**Table 8.3 Guidelines on the number of bat activity surveys recommended to achieve a reasonable survey effort in relation to habitat suitability.**

| Survey type | Low suitability habitat for bats[a] | Moderate suitability habitat for bats | High suitability habitat for bats |
|---|---|---|---|
| Transect/spot count/timed search surveys | One survey visit[b] per season (spring – April/May, summer – June/July/August, autumn – September/October)[c] in appropriate weather conditions for bats<br>Further surveys may be required if these survey visits reveal higher levels of bat activity than predicted by habitat alone | One survey visit[b] per month (April to October)[c] in appropriate weather conditions for bats. At least one of the surveys should comprise dusk and pre-dawn (or dusk to dawn) within one 24-hour period. | Up to two survey visits[b] per month (April to October)[c] in appropriate weather conditions for bats. At least one of the surveys should comprise dusk and pre-dawn (or dusk to dawn) within one 24-hour period. |
| AND | | | |
| Automated/static bat detector surveys[d] | One location per transect, data to be collected on five consecutive nights per season (spring – April/May, summer – June/July/August, autumn – September/October)[c] in appropriate weather conditions for bats | Two locations per transect, data to be collected on five consecutive nights per month (April to October)[c] in appropriate weather conditions for bats | Three locations per transect, data to be collected on five consecutive nights per month (April to October)[c] in appropriate weather conditions for bats |

[a] If the habitat has been classified as having low suitability for bats, an ecologist should make a professional judgement on how to proceed based on all of the evidence available. It may or may not be appropriate for bat activity surveys to be carried out in low suitability habitats. However, caution should be exercised in fringe areas (e.g. some areas of Scotland) where 'low suitability habitat for bats' may be extremely important to local bat populations due to the relative scarcity of better habitats. In such situations, bats are likely to also be more widely dispersed and may use a larger number of sites, therefore survey effort may actually need to be increased to detect use on the proposed site in question.

[b] A survey visit should aim to cover all habitats represented in the survey area that could be impacted by the proposed activities. This may consist of a single transect carried out on a single night for small sites (e.g. small housing developments) with low habitat diversity but could range up to multiple transects carried out over one or several nights (depending on number of ecologists) on a larger site (e.g. road schemes) with greater habitat diversity.

[c] April, September and October surveys are both weather- and location-dependent. Conditions may become more unsuitable in these months, particularly in Scotland, which may reduce the length of the survey season.

[d] Detector locations should be assigned to cover all habitats represented in the survey area that could be impacted by the proposed activities. This could mean a single detector location at a small site with only one habitat represented but could range up to many detector locations on larger sites. Automated/static surveys are particularly useful when assessing collision risk, e.g. detectors can be placed at crossing points on proposed roads or railways.

Note: Multiple survey visits should be separated by at least two weeks, preferably longer, to observe temporal changes in activity.

Survey data should be analysed as soon as possible and preferably before the next survey (see Section 10.2).

It is important to consider how effective the surveys are in recording species that are more difficult to detect (see Section 3.9) or exhibit highly variable or seasonal patterns of activity. It may be appropriate to adjust the survey methods, increase the number of survey nights or adjust the survey frequency to ensure these species are not under-recorded. Skalak *et al.* (2012) reported that relatively few nights are needed to detect common species but longer sampling periods may be necessary to detect rarer species. The same is true of those species that use quiet echolocation calls (see Table 3.8 on page 32).

Comparing transect and static data may also indicate that species are being recorded by one type of survey but not another, so that subsequent surveys can be adjusted accordingly.

### 8.2.8 Weather conditions

Please refer to Section 2.6.1 for guidance on weather.

### 8.2.9 Next steps

The next steps will depend on what has been recorded during the activity surveys. It may be necessary to carry out more targeted activity surveys in subsequent years or use alternative methods to gain specific information (e.g. using a trapping survey to distinguish between *Myotis* or *Plecotus* species or to define breeding status of the bats; see Chapter 9).

Where enough information has been collected, the data should be used to inform an impact assessment and the design of a mitigation strategy.

## 8.3 Swarming surveys – acoustic

### 8.3.1 Description and aims

Swarming surveys are carried out to identify if a site is used by bats for autumn swarming, which was described by Fenton (1970) as 'the flight of bats through hibernacula in late summer and early fall'. This usually occurs in the UK from August to October inclusive and activity peaks 3–4 hours after sunset (Rivers *et al.*, 2006; Glover and Altringham, 2008): observations made during the first 2–3 hours after sunset may not detect it. Autumn swarming should not be confused with what is commonly termed 'dawn swarming', where one or more bats fly around outside their roosts prior to entry at dawn.

Autumn swarming behaviour has been recorded mostly at the entrances to and outside underground sites such as caves, mines and tunnels but has also been observed around other structures such as castles, and large barns. Evidence from the Netherlands shows mass swarming events of common pipistrelle bats in the autumn followed by mass hibernation in a diverse range of building types in urban environments (Korsten *et al.*, 2015). This phenomenon requires some research in the UK but ecologists should be aware of the potential for larger numbers of this species to be present during the autumn and winter in large buildings in highly urbanised environments.

Swarming behaviour is common among *Myotis*, *Plecotus* and *Barbastella* species. Swarming probably has several important functions: mating, transfer of information about hibernation sites to young, collection of information on the condition of hibernation sites prior to hibernation and migration stopover, but as yet most lack direct evidence to support them. There is, however, good behavioural and genetic evidence to show that mating is an important function (Thomas *et al.*, 1979; Kerth *et al.*, 2003; Rivers *et al.*, 2005; Furmankiewicz and Altringham, 2007).

Rivers *et al.* (2006), in a study of four North Yorkshire caves, found that Natterer's bats undertook seasonal migration between the caves and their nursery sites over at least a 60km radius area. Between 300 and 400 bats visited the caves each night, with many more at the peak of the season. Numbers of bats vary between sites and from night to night at the same site. Activity typically starts in August and rises to a peak in September or early October before slowly declining. Many thousands of bats may visit some sites, but swarming behaviour may involve no more than a few bats each night at minor sites.

Swarming sites can therefore be important mating sites for large numbers of bats and are important for gene flow (Kerth *et al.*, 2003; Rivers *et al.*, 2005; Furmankiewicz and Altringham, 2007). Many underground swarming sites are also hibernation sites and it is likely that those bats swarming at a site go on to hibernate in the same site (Glover and Altringham, 2008). Individual bats show very high fidelity to a single swarming site (Rivers *et al.*, 2005, 2006; Glover and Altringham, 2008) and few bats are recaptured at other sites, even those close by.

The impact of destroying or changing a swarming site for development purposes is likely to be severe, so it is particularly important to investigate further whether swarming is a possibility. The aim of carrying out acoustic bat activity surveys at potential swarming sites is to establish actual use of the site by swarming bats and understand how bats use the site. If a site likely to be impacted by development does support swarming bats it is possible that further surveys will be necessary (see Chapter 9).

### 8.3.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 8.3.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. Acoustic swarming surveys are unlikely to disturb bats if carried out correctly; however, it is good practice for these surveys to be designed and carried out, or at least led, by licensed surveyors who have gone through a period of training and evaluation. If disturbance to bats is likely (e.g. because an ecologist needs to deploy a detector in the entrance to a roost), then a survey licence is required.

### 8.3.4 Methods

The simplest and most efficient way to investigate whether bats are swarming at a site is to deploy an automated/static bat detector and recorder to record swarming bats just outside or within the entrance to an underground site (or complex structure). Repeated peaks in ultrasonic activity, reaching a maximum 3–4 hours after sunset, indicate the site is used by swarming bats and the echolocation calls recorded can be analysed to species or genus after the survey. This method is likely to generate a large amount of data at a swarming site because of the high levels of activity generally observed. However, it is unlikely to be necessary to scrutinise all recordings made, depending on the aims and objectives of the survey. Alternatively, data collected could be reduced by recording for only a few hours during the middle of the night (e.g. 2–5 hours after sunset).

### 8.3.5 Complementary methods

It may be appropriate to trap bats at a swarming site if it is necessary to confirm species, particularly if Annex II species such as barbastelle and Bechstein's bat may be present. Wherever and whenever possible, harp traps should be used in preference to mist nets due to the possibility of catching large numbers of bats. More information on trapping is provided in Chapter 9. With the evolution of more reliable software for automated identification from echolocation calls, trapping to determine species only may eventually become unnecessary.

Trapping to establish gender is unnecessary because the pattern of use at swarming sites is well documented: both sexes are present, but males outnumber females, consistent with mating behaviour during swarming (Thomas *et al.*, 1979; Kerth *et al.*, 2003; Parsons *et al.*, 2003a; Rivers *et al.*, 2005; Furmankiewicz and Altringham, 2007; Glover and Altringham, 2008).

### 8.3.6 Timing

Swarming surveys should be carried out from mid-August to October inclusive, but if only a limited survey period is available mid-September to early October is best. Species composition varies throughout the swarming season, with *Plecotus* and most *Myotis* species either peaking early or showing no discernible peak, and Natterer's bat peaking late in the season (Parsons *et al.*, 2003b; Rivers *et al.*, 2006; Glover and Altringham, 2008). Bechstein's bat, Alcathoe bat and barbastelle also swarm, but numbers caught are too low to reveal temporal patterns. Most sites have a similar mix of species: brown long-eared bat and the *Myotis* species expected in the area. It is typical for Natterer's bat to greatly outnumber all other species, particularly from mid-season onwards. Non-swarming species may also be recorded, particularly horseshoe bats, depending upon the nature of the adjacent habitat.

### 8.3.7 Survey effort

At least five nights of survey with an automated/static detector (in appropriate weather conditions for bats; see Section 2.6.1) in each month of the swarming season of mid-August to the end of October is recommended to establish whether a site is used for swarming or not.

If trapping is undertaken, then recommendations on survey effort are provided in Chapter 9.

### 8.3.8 Weather conditions

Please refer to Section 2.6.1 for guidance on weather.

Many studies have noted that bat activity at swarming sites varies markedly from night to night: bat activity is significantly suppressed by rainfall and positively correlated with residual maximum ambient temperature. Grubb (2012) also found high winds depressed activity. Moon phase does not appear to influence swarming activity (Parsons *et al.*, 2003a), but a bright moon has been known to lower capture success (if trapping) at exposed locations. Swarming activity appears to be more likely when weather conditions are more stable so targeting periods of high pressure may be appropriate.

### 8.3.9 Next steps

See Chapter 9 regarding trapping bats at swarming sites. This is only likely to be necessary if Annex II species may be present. If the presence of Annex II species is unlikely, then trapping is less appropriate because species assemblages using swarming sites are well documented from other studies (Parsons *et al.*, 2003b; Rivers *et al.*, 2006; Glover and Altringham, 2008).

Swarming sites are also used for hibernation so it may be necessary to also carry out hibernation surveys as described in Section 5.3.

## 8.4 Back-tracking surveys

### 8.4.1 Description and aims

**Back-tracking surveys** involve ecologists making visual observations of bats commuting away from their roosts at sunset or commuting back to their roosts at sunrise then attempting to track back to the roost based on these observations. Bat detectors are also used to record echolocation for identification of species, where possible. This technique was first developed in the Netherlands and is based on four principles:

- The earlier a bat is seen after sunset or the later it is seen before sunrise, the closer it is likely to be to its roost (the exact time depends on the species).
- Bats fly away from their roost at sunset, so ecologists should move in the opposite direction as the bats at this time to locate the roost.
- Bats fly towards their roost at sunrise, so ecologists should move in the same direction as the bats at this time to locate the roost.
- At sunrise, some bats species swarm at roost access points for between 10 and 90 minutes before entering.

The aim is to find roosts by making observations of commuting bats. These surveys are often used after a bat activity survey if numbers of bats were seen all commuting in one direction and follow-up is required or in situations with lots of potential roosts sites that are difficult to survey using alternative methods (e.g. in woodlands or highly urbanised areas).

### 8.4.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1.

### 8.4.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences. Back-tracking surveys are unlikely to disturb bats if carried out correctly; however, it is good practice for these surveys to be designed and carried out, or at least led, by licensed surveyors who have gone through a period of training and evaluation. If disturbance to bats is likely (e.g. because an ecologist would needs to investigate the roost when found using a torch or endoscope), then a survey licence would be required.

### 8.4.4 Methods

Ecologists should be deployed on potential or actual commuting routes close to roost sources (identified during the preliminary ecological appraisal, see Chapter 4, or during activity surveys, see Section 8.2) and note the time and direction of travel of each bat encountered on a detailed plan of the site. The ecologists should move in the opposite direction to the bats at sunset and in the same direction as the bats at sunrise. As ecologists approach potential roosts they should watch for bats emerging or dawn swarming at roosts.

If multiple ecologists are used they should be in constant contact via hand-held radio to communicate their observations. The data from multiple ecologists can also be pooled for a bigger picture of bat activity across the site, which can be used to design subsequent surveys where necessary.

In theory, back-tracking surveys work best for species with loud echolocation calls which form large roosts, but they can potentially be used to locate the roosts of any bat species.

### 8.4.5 Complementary methods

Back-tracking surveys are rarely used in isolation; they are most effective when combined with roost (Chapters 5 to 7) and bat activity surveys (Section 8.2).

### 8.4.6 Timing

As back-tracking surveys are most effective for larger roosts, the best time to carry them out is between May and August, when maternity colonies are gathered. However, results may be gained if carried out in April, September or October, depending on the individual situation (although October surveys are not considered appropriate in Scotland). See Section 8.2.6 for further comments on timing of activity surveys through the year. Table 8.4 gives recommended timings for back-tracking surveys during the night.

**Table 8.4 Recommended start and end times for back-tracking surveys.**

| Survey type | Start time | End time |
|---|---|---|
| Back-tracking survey at dusk | 15 minutes before sunset | When it is too dark to observe bats or when the source roost has been found |
| Back-tracking survey at dawn | 2 hours before sunrise | When bats cease to be active or when the source roost has been found |

Timings may be adjusted (earlier or later) if necessary by the ecologist, bearing in mind the site-specific circumstances, although this should be justified in the survey report.

### 8.4.7 Survey effort

The survey effort for back-tracking surveys is not fixed. These surveys have the specific aim of locating roosts using commuting bats for guidance and should be continued until this aim is reached unless alternative methods are considered more appropriate.

### 8.4.8 Weather conditions

Please refer to Section 2.6.1 for guidance on weather.

### 8.4.9 Next steps

If a roost is found during a back-tracking survey it may be necessary to follow up with a roost characterisation survey (see Section 7.2) to count the numbers of bats present at the roost.

Chapter 9

# Advanced licence bat survey techniques

## 9.1 Introduction

Being small, nocturnal and with many species being morphologically and acoustically similar, bats remain one of the most challenging groups of species to study for the purposes of determining impacts from development, especially when working to the deadlines often associated with a commercial project. While research on the ecology of some bat species is widely available, there are still significant gaps in the knowledge about the basic ecological requirements of many species. Radio tagging and tracking surveys are therefore powerful survey tools to obtain information on bats and bat populations potentially affected by a proposed development. However, radio tagging and tracking surveys do involve significant levels of risk to bats, and therefore these guidelines have been written to take account of Eurobats Resolution 4.6, which provides guidance on the capture and study of captured wild bats.[45]

This chapter provides guidelines on using ALBST and principally concerns the trapping of free-flying bats and, where required and appropriate, the subsequent attachment of radio transmitters. The techniques covered in this chapter need to be specifically licensed by the relevant licensing authority.

Deciding to use ALBST is a process of balancing the data requirements to meet the objectives of the survey with the level of potential impact on bats or bat populations from using the technique. The decision-making processes should also fully consider the potential level of impacts from the proposed development (see Section 2.2). More detailed information gained from ALBST is likely on projects with greater impacts on 'difficult to survey' bat species such as tree-roosting or quiet-calling species; more sensitive bat populations, such as Annex II bat species generally; SACs or SSSIs designated for bats; or in particular habitats such as woodland. However, it should be recognised that using such techniques also poses a risk to sensitive bat populations.

A point of principle is that where the required information can be obtained using non-invasive techniques, these should be used first. However, while non-invasive methods of surveying bats such as bat activity surveys have dramatically improved data gathering for development-related projects, such techniques have limitations. In particular, confidence in identifying bat species such as *Myotis* bats (unless species-specific behaviour has been observed, as is the case with Daubenton's bats flying close to the surface of water) is extremely difficult (Parsons and Jones, 2000; Walters *et al.*, 2012). In addition, quiet echolocating species (or those that do not call while foraging) often go under-recorded and non-invasive survey methods are generally unable to confirm the sex, age class or breeding status of individual bats, especially away from the roost.

If the potential impact of development activities is unlikely to significantly affect bats or their habitats, this should be reflected in the survey design and the use of ALBST is unlikely to be necessary. Equally, projects or developments (of any scale, from small barn conversions through to major road schemes) that are likely to have high direct or indirect impacts on bats (particularly for rarer or uncommon species or at the landscape level where impacts may affect multiple bat species and populations) will be required to have much more detailed data sets, potentially justifying the use of ALBST. Box 3 provides an example of the effective use of ALBST.

**Box 3 Example of effective use of ALBST.**

A series of trapping and simultaneous full-spectrum bat detector surveys were undertaken in the same woodland habitat over six months during the bat active period of 2014. In total, 82 bats were captured and approximately 3500 bat recordings were made over 17 survey nights. Only six bat detector recordings could be assigned to long-eared bats whereas 41% of the bat captures were of brown long-eared bat. Furthermore, three Bechstein's bats, two of which were from a nearby newly discovered breeding population, were captured. These results highlight the significant under-recording of species that listen rather than echolocate and where trapping is often the most effective tool to confirm their presence. Given the scale of the housing development proposals (over 5000 units), the potential impact on the woodland from the development (lighting and increased recreational use), as well as the possible presence of rare species in the general area, the use of ALBST was appropriate and provided information to inform the EIA that other techniques could not achieve.

[45] Found at http://www.eurobats.org/sites/default/files/documents/pdf/Meeting_of_Parties/MoP4_Res.6_ Issue_of_Permits.pdf) and states that 'radio-telemetry should only be used for well-organised and authorised projects where essential data cannot be acquired with less-intrusive methods'.

Radiotelemetry can provide valuable data on roost use, activity patterns, colony and individual home ranges, foraging behaviour and habitat use. For impact assessments associated with development, this data can provide useful context on how important a proposed site might be within a bat population's home range and whether preferred foraging, commuting or roosting habitat types will be affected, enabling the design of more effective mitigation. Furthermore, radiotelemetry can locate roosts of challenging species (especially in trees).

It is important to highlight that radio tracking surveys are essentially population sampling methods. It is never necessary or desirable from a bat welfare perspective to mark every animal from a population, and only sufficient bats to confidently represent the population being investigated should be tracked. However, this approach can be misrepresented in development projects as the focus for impact assessments and/or mitigation is often on only the individual bats being tracked and their movements, rather than using the sampling to identify which **type** of commuting routes or foraging habitats the population is likely to use. This issue is best overcome by proper study design and statistical testing of the samples used. All effort should be made to extract as much information as possible from a marked individual to justify the method. It is not considered acceptable given the intrusive nature of the methods on bats and the costs of such surveys, for any subsequent analysis to be limited to simple dots on a map, unless roost location is the only objective. More information is provided in Section 10.4.

As highlighted earlier, this technique should only be used in cases where other options for obtaining data are ineffective or grossly inefficient and the level of potential impact on important bat populations is considered high, such as the loss of significant high-quality bat foraging or roosting habitat. For instance:

- High-impact developments at a landscape scale that may affect substantial roosting and foraging areas for a wide assemblage of bat species, especially those difficult to identify through bat detector systems.
- High-impact developments at a landscape scale affecting rare bat species, for example, Annex II species or features of SSSIs.
- High-impact developments on areas likely to support proportionately higher populations of tree-roosting bats or bats likely to be in inaccessible roost types (quarry faces, etc.), where other methods have not been able to locate roosts likely to be present.

Although these guidelines are focused on single-site/project-related developments, radio tracking of key populations can also be effectively used to provide a strategic approach to land use/development-related planning, particularly around sites supporting Annex II species. For instance radio tracking can be used to identify key habitats and sustenance zones around bat SACs to inform HRAs and local development plans. This is likely to be more efficient and productive than undertaking a site-by-site approach to gathering such information.

These guidelines should be read in conjunction with NE's advice regarding the use of these techniques (WML-G39 2013, NE, 2013).

## 9.2 Trapping surveys

### 9.2.1 Description and aims

This section focuses on the capture of free-flying bats with mist nets and harp traps. This technique can be used at bat roosts, bat swarming sites and bat commuting and foraging areas.

Given its rarity, quiet echolocation calls and the difficulty of reliably separating *Myotis* bats from echolocation calls (Parsons and Jones, 2000; Walters *et al.*, 2012), species-specific guidelines are given for surveying Bechstein's bats where developments are likely to affect this species and/or its habitats.

The need to undertake trapping surveys will depend on a range of factors and, in particular, the questions requiring answers to inform an impact assessment. Recommended use of these techniques include:

- To determine species identification: for instance if bat detector surveys have found proportionately high levels of *Myotis* bat activity and the development is likely to have a high impact on the habitats of such species, then it will be important to confirm which *Myotis* species are present to inform the impact assessment and mitigation strategy. It is also essential to identify bats to species level for high-impact licensing purposes when other techniques have been unable to do so.
- To determine gender and breeding status: trapping can be used to determine gender and breeding status and is particularly important when the impacts of a development on a roost or site are high (i.e. full destruction) and knowing the breeding status of a population is crucial to designing the most appropriate mitigation. In addition, understanding the breeding status of bats using foraging or other non-roost sites can be an important element of valuing the importance of the site for impact assessment purposes.
- To gain further information about rare or under-recorded bats: the presence, gender, breeding status, roost locations, foraging areas and commuting routes of rare species such as grey long-eared bat, barbastelle and Bechstein's bat may need to be confirmed where they could be present and when their potential habitat is affected by the proposed development.
- To find tree and building roosts at a landscape level: if high impacts on bats are anticipated, then trapping can be used to determine the presence of breeding bats and the selection of such individuals for the attachment of radio transmitters. This is an effective approach to locate breeding colonies, particularly tree roosts.

It should be noted that trapping surveys also have their own biases and limitations and may be more effective at determining the presence of certain species (for instance those species generally found in cluttered habitats). Data collected using this technique should be considered alongside other techniques to provide a balanced data set of bats using any particular site.

### 9.2.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1 and further information about mist nets, harp traps and lures is provided in Appendix 5.

### 9.2.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences.

These techniques can significantly affect the welfare of bats and therefore bat handling and identification skills need to be regularly practised to be able to extract and process bats quickly. Experience of handling wild bats from a range of species including small, medium and large bats should be kept up to date.

If acoustic lures are used (see Section 9.2.5), continual training or experience in the most effective use of lures is recommended, because of their evolving nature.

Licences from the relevant licensing authority (see Section 1.2.2) are required to use these techniques, including the use of lures. Using lures without traps to attract bats also requires a licence.

### 9.2.4 Methods

The first stage of a trapping survey is the identification of potential trapping sites through a review of site plans, aerial imagery, the proposed activities and any existing habitat/bat-related data. This information helps to identify the sites that would increase the likelihood of catching bats in relation to those areas impacted by the proposed development. This should be followed by a daytime site visit to determine the micro-siting of the traps. Large projects involving multiple trapping sessions will require the relevant project licence and broad trapping locations and methods will be required as part of any project proposal when applying for a licence.

Trapping using mist nets and harp traps can be passive (without lures) or active (with lures used to attract bats; see Section 9.2.5). The set-up and location of traps and nets will vary depending on which method is being used and whether specific species are being targeted. Passive trapping with mist nets and harp traps should be based on the principle of pinch points or funnelling the bats to the traps. Mist nets have the advantage of covering more space and being lighter, but they require continuous monitoring and higher levels of bat handling skills to extract bats. Bats are more easily extracted from harp traps; however, they cover less trapping area and are heavy.

Recommended trapping locations include areas where vegetation or other structures limit the space through which bats can fly or manoeuvre, therefore increasing the chance that the bat will fly through the restricted space where the net or trap is located, for instance:

- woodland rides and edges with overhanging tree branches;
- streams/river corridors and bridges;
- low-hanging branches from large isolated trees;
- gaps in treelines/hedgerows;
- next to water features such as lakes/rivers, especially adjacent to riparian woodland;
- tunnel, cave and mine entrances and passages; or
- barn doors.

Placing traps next to building features such as hanging tiles are also effective when trapping at building roosts or swarming sites (see Mitchell-Jones and McLeish, 2004, for more detailed information on such techniques).

Where larger numbers of bats are expected, harp traps are likely to be safer than mist nets because of the need to extract bats from mist nets soon after they have flown in.

It is essential to ensure when working in or around water that bats will not be drowned if they become trapped and their weight drags the net or capture bag into the water.

**Mist nets should be monitored continuously when deployed,** ideally using night-vision equipment or, as a minimum, a bat detector to monitor any bat activity around the net. Following any bat detector activity (or at 5-minute intervals) nets should be checked to ensure captured, quiet-echolocating bats do not remain unnoticed. Nets should be checked with a powerful torch (ideally with a red filter to preserve night vision) very quickly to avoid putting off bats that may otherwise fly into the net. Harp traps should be checked ideally every 15 minutes.

Where a bat is caught it should be extracted from the mist net or harp trap as soon as possible and released by the ecologist after obtaining the minimum information (which should be labelled with date and time of capture and trapping location) as follows:

- species;
- sex;
- age class (where possible);
- breeding status (pregnant/lactating/post-lactating/non-breeding).

Processing bats should be carried out as quickly as possible to obtain the data required. Ideally bats should be handled as little as possible and released nearby within minutes of being captured. This is especially important for breeding females or during the cooler active months such as September and October. Non-target species, stressed or heavily pregnant bats should be released immediately with no processing. If heavily pregnant bats are being caught unexpectedly then consideration should be given to ceasing trapping entirely.

Forearm or other morphological measurements are generally used to help identify the bat species, therefore prolonged handling for these purposes should only be undertaken where identification is proving challenging. If species identification can be made without taking such measurements, then this part of the process is generally superfluous. Furthermore, for commercial surveys, weight data is only of use where bats are to be marked with radio transmitters, therefore it is unnecessary to weigh bats for trapping purposes as this adds unnecessary time to the processing, potentially creating problems for release.

While the bat is under the control of the ecologist, it is important to ensure the equipment used to hold the bat(s) and the processing stages comply with licensing conditions and guidance (e.g. NE, 2013).

Bats should be released at height and for most species releasing at head height is sufficient. Noctule bats may struggle to launch at this height and it is often necessary to find a suitable tree and allow this species to climb to a height where it is comfortable to launch. When releasing bats it is important to continually monitor behaviour to identify whether bats are fit to release and have launched successfully.

### 9.2.5 Complementary methods

Bat activity surveys (see Chapter 8) are complementary to trapping and can provide a more balanced data set than trapping alone, subject to the objectives of trapping. Care should be taken to ensure that acoustic surveys do not record calls emitted by the lures (see below) when trapping and acoustic surveys are undertaken simultaneously in the same locations.

Where sites are located within the known distribution of Bechstein's bat and suitable habitat for this species is likely to be impacted (see Bat Conservation Trust, 2013) then species-specific surveys are likely to be required. Mist nets and/or harp traps used with a lure emitting Bechstein's bat social calls is the recommended method of surveying for Bechstein's bats as these bats use quiet echolocation and even when detected using bat detectors they are very difficult to distinguish from other *Myotis* bat species (Parsons and Jones, 2000; Walters *et al.*, 2012). The use of a lure constitutes active trapping and, for this species, traps and lures should be placed in the cluttered interior area of woodland. This technique has been used to great effect with Bechstein's bats (Hill and Greenaway, 2005; Davidson-Watts, 2008; Miller, 2012).

Acoustic lures should be placed close to the net or harp trap. For harp traps, the most effective technique appears to be placing the speaker just above the catch bag in the centre of the trap as bats are more likely to be caught by the lower parts of the strings of the trap and have less time to escape. Net configurations vary and so the positioning of the lure will also vary. However, placing the lure or speaker close to the mist net will increase the chance of a Bechstein's bat being captured as it investigates the lure. Some do's and don'ts relating to lures are as follows:

- Do place lures and/or lure speakers close to the trap or net, as this increases the chance of the Bechstein's bat being captured when investigating the lure.
- Do move lures between traps and nets where there are more traps/nets than lures as this is more effective than having a stationary lure, which bats may become accustomed to. This also provides greater coverage of a site.
- Do play recognised, tested and effective Bechstein's bat social calls.
- Do have periods of silence to determine whether bat activity is present around the nets when not using the lure.
- Do consider turning the lure off during extraction to avoid unnecessary stress to the bat, particularly when extracting bats from mist nets.
- Do not use high volumes as abnormally loud calls could be counterproductive by deterring Bechstein's bats, particularly those using cluttered habitats.
- Do not use bat distress calls because the meaning of distress calls to bats is poorly understood and has the potential to have negative consequences for local populations.
- Do not use lures within 50m of known active roosts, including near bat boxes that may contain a roost, as this may cause prolonged disturbance to bats present at the time.
- Do not use lures within 100m of swarming sites during late summer/autumn as this may cause prolonged disturbance to bats present at the time.

Some precautionary advice on the use of lures is provided in Box 4.

**Box 4 Precautionary note about the use of lures to aid the capture of bats in traps and nets.**

Although lures have been in use by various bat researchers and bat workers since the late 1990s, very little is known about the full effects these devices have on local bat populations. They have been shown to be very effective at increasing capture rates with harp traps and mist nets, particularly in more cluttered habitats such as woodlands and with certain species. However, no significant research has been undertaken to consider whether there are any detrimental effects of using them so they should be used with caution when all other methods have been considered and only with very specific aims and objectives.

More information on acoustic lures is provided in Appendix 5.

### 9.2.6 Timing

Subject to environmental conditions, trapping surveys for development-related projects should normally be undertaken between May and October when bats are most likely to be active (but not in the potentially vulnerable post-hibernation period of April unless there is a specific requirement approved under a project licence). The exact timing of the surveys will largely depend on the objectives and the potential bat habitat of the site affected. For instance, the most appropriate time to survey a potential swarming site would be between August and October, whereas trapping to confirm the presence of breeding bats should be undertaken between May and August. Unless clearly justified through the project aims, it is recommended that trapping during the period of June to mid-July is not carried out to reduce the risk of unnecessarily catching heavily pregnant bats or bats with dependent young. Trapping during this period is best covered by the relevant project licence rather than class licence.

NE Class licences (Level three for mist netting and Level four for harp trapping; see Section 1.2.2.) allow for a maximum of three trapping nights per site for commissioned developments without a specific project licence (this is not the case for the other UK countries, where the relevant project licence is required). Therefore when these techniques are used as a complementary method to other survey techniques (i.e. not under the relevant project-specific licence), such as bat activity surveys to identify *Myotis* species or surveys for under-recorded species such as Bechstein's bat, it is recommended that at least three trapping surveys are undertaken. These surveys should be spaced across the bat active season with one survey in May, a second survey in July/August and the third survey in August/September in suitable weather conditions. Trapping the same trap site locations more than once a month would require some justification from a disturbance perspective. Should more trapping sessions be required to meet specific objectives, then a project licence would be required.

On the day of the trapping survey, ecologists would normally need to arrive at the proposed trapping site(s) at least an hour before sunset to confirm exact trapping points, identify any additional health and safety issues, and set the traps. A trapping survey would usually commence at dusk and continue until 2–3am depending on conditions, capture success, general bat activity and the objectives of the survey. For instance if the objective was to capture a specific bat species for radiotelemetry, then trapping would cease once the target bat or bats have been captured. When trapping for swarming surveys, activity is likely to peak much later in the night (see Section 8.3.1) and therefore survey timings should be adjusted accordingly.

### 9.2.7 Survey effort

Survey effort depends on a number of factors including the size of the site, the type and quality of habitats present and the objectives of the survey. For instance surveys to trap specific species for radiotelemetry will require an assessment of suitable habitat both on and off the site, a review of previous records and an appraisal of suitable trapping areas to determine the effort required to meet the objective.

The number of harp traps/mist nets that are deployed simultaneously will depend on the extent of habitat to be surveyed. Traps/nets should ideally be no less than 100m apart when using lures.

For smaller projects where impacts are more confined to specific areas of high-quality habitat, at least three trapping surveys should be undertaken over the active period, in line with other bat activity/survey methods during late spring, summer and autumn (see Section 8.2.7), with priority areas being woodlands, treelines and wetland areas. The number of traps/nets will vary depending on the size of the areas being surveyed and the species likely to be encountered.

Large infrastructure schemes involving impacts on high-quality bat habitat such as deciduous woodlands, treelines and wetlands, with multiple trapping objectives such as the confirmation of breeding bats and the determination of bat assemblages, are likely to require many trapping nights with multiple harp traps and/or nets being used simultaneously over a 5- or 6-month period during the active bat season, especially if rarer (e.g. Annex II) or significant levels of tree-roosting species are predicted to be present. In some situations, trapping surveys over consecutive years may be relevant.

See Box 5 for more information on survey effort for Bechstein's bat.

**Box 5 Survey effort for Bechstein's bat using traps and lures.**

To determine the presence/likely absence of Bechstein's bat on a site, the lure and net/harp trap method should be used and trapping surveys conducted for a *minimum* of six trap nights over the active bat season. One trap night is one lure and net or harp trap combination on one night. Therefore, six trap nights can be achieved by three nights of trapping with two sets of trap/lure combination. Ultimately the total number of traps/nights will depend on the size and nature of the potential Bechstein's bat habitat available. If the site is large with multiple woodland copses or treelines with potential for this species, then more trap nights are likely to be required.

Trapping surveys for Bechstein's bats should be undertaken across the active bat season to ensure that the key stages of the breeding cycle are covered, with ideally one survey pre-parturition and one survey post-parturition between May and August, at least one month apart.

### 9.2.8 Weather conditions

Please refer to Section 2.6.1 for guidance on weather.

Effective trapping is subject to environmental conditions as traps are generally less effective in wet and windy conditions. This is more relevant to mist nets than harp traps, where water droplets and wind can make nets more visible to bats. In addition, trapping bats in cool and wet conditions can seriously affect their welfare, because they may go torpid in harp traps, making effective release more difficult.

Weather forecasts should always be consulted before a survey is carried out, to identify whether conditions will be favourable for trapping. **Trapping should be avoided during periods of prolonged rain (more than isolated showers, where trapping can be briefly suspended), and trapping should not be undertaken in temperatures below 8°C**, unless duly authorised by a project licence, because bats are likely to be much harder to release effectively (in any case, activity levels would most likely be low and the data produced would be constrained).

### 9.2.9 Next steps

Trapping is usually one of the last techniques to be used to obtain data about bats using a site, and should provide a great deal of useful information to properly inform an impact assessment. However, should the presence of rare species be confirmed and/or the results suggest that more information on tree-roosting bats is required, then the next step may be radiotelemetry (see Section 9.3), or more focused activity such as roost surveys (see Chapters 5 and 6).

Some bats such as whiskered, Brandt's bat and alcathoe bat are very difficult to identify in the hand and photographs may need to be taken for further analysis. In addition droppings from these bats (when left in clean holding bags) can be collected and sent for species identification via DNA analysis (see Appendix 4). Various universities and private companies offer this service.

## 9.3 Radio tagging/telemetry surveys

### 9.3.1 Description and aims

The aim is to effectively **mark a target bat with a radio transmitter for radiotelemetry** to obtain location data and determine the following:

- Location of roost sites
- Population and individual home ranges and core areas
- Habitat use
- Activity patterns and distances travelled

When properly analysed, location data obtained through radiotelemetry should be able to help identify how the proposed development site relates to the bat population's home range, core foraging/flying or commuting habitats and roost sites (see Section 10.4), thus enabling an effective impact assessment and, where necessary, a mitigation strategy to be developed.

### 9.3.2 Equipment

Generic documentation/equipment required for field surveys for bats is provided in Section 2.5.2; survey-specific equipment is listed in Appendix 1 and more information about radio tags, receivers and antennae is provided in Appendix 6.

### 9.3.3 Expertise and licences

Section 2.5.1 discusses expertise and Section 1.2.2 provides information on licences.

There are a number of different skills sets involved in radio tagging bats:

- **Survey design and scope** – to design an effective radio tracking survey, ecologists require a full understanding of the ecology of the bat species concerned and have experience of the practical application of these techniques, as well as data collection and analysis methods to obtain the appropriate information to inform the survey objective. No licence is required to undertake this task/role; however, it is unlikely that a suitable scope of works can be developed by ecologists without sufficient experience in using these techniques on the ground.
- **Tagging bats** – these techniques can significantly affect the welfare of bats and therefore ecologists undertaking this task require very good and regularly practised handling skills to be able to process bats and affix transmitters quickly and effectively. This task is subject to licensing from the relevant licensing authority.
- **Radiotelemetry** – a basic understanding of the physics of radio waves (when tagging with radio transmitters) is required as ecologists need to understand the limitations of this technique and how signals from transmitters are manipulated by the environment. Ecologists will also require excellent map reading, compass and navigation skills to be able to plot bat locations and take accurate compass bearings at night.

### 9.3.4 Methods

A significant amount of useful information on radiotelemetry design, field tracking and analysis techniques can be found in Kenward (2001). Welfare issues are covered in some detail by NE's guidance note WML-G39 (NE, 2013).

Highlighted below are the key steps and considerations that are important for bat-related tagging and tracking for development-related projects in the UK.

- **Survey design** – this stage is crucial and should be undertaken before the bat active season. Survey design will depend on the objectives of the survey. For instance, the approximate number of bats to be marked will need to be calculated/estimated. Sampling size is one of the most important factors in designing a radio tracking survey; resources should be prioritised to track more bats for less time rather than fewer bats for more time. For surveys to determine habitat use, more bats (the sampling points) than habitat categories are required to be able to use compositional analysis (a common statistical method for robust habitat preference of radio-tracked animals; see Section 10.4). This is likely to be more than five bats and may be more depending on colony size and could involve multiple species, depending on the scale and impacts of the project. There are likely to be differences in behaviour between breeding and non-breeding bats, and between different sexes and age classes (adults/juveniles). It will therefore be important to clearly identify the target bats and the reasons these are being sampled.

- **Landowner access (for off-site tracking)** – this needs to be arranged and, if this becomes a major limitation to data collection, a plan of how data will be collected from roads or other public areas (although rights of way comprise a right to cross the land, not to undertake any other activity such as survey).

- **Resource planning and licensing** – appropriate resources will need to be allocated in terms of equipment, such as tags and receivers and tracking teams. Tags and equipment will need to be ordered from suppliers with plenty of notice. It may be appropriate to check licensing turnaround times to give more confidence in timescales, particularly for bigger projects where the manpower and associated logistics need to be booked well in advance.

- **Tagging bats** – when a target bat is captured either in the roost or the wider countryside, it should be weighed initially to both ensure it is a good weight for that species and that it meets the weight requirements for tagging. Radio transmitters should be no more that 5% of total body weight. The bat should be checked over to evaluate whether it appears healthy, in good condition and is free from injury or damage. Species, age, sex and breeding status should be noted. Tagging mothers with dependent young within the roost is not recommended. All UK bats are marked by fixing the transmitter dorsally between the shoulder blades with the antenna trailing behind the bat. Fixing with suitable glue involves carefully parting or trimming the fur and applying glue to the fixing location on the bat and glue to the transmitter before attaching the tag. It can take between 10 and 30 minutes for the glue to cure sufficiently before releasing a bat. Bats should not be held for more an hour. Bats should be released (see Section 9.2.4) and post-release observations made for up to an hour to ensure the bat can fly freely and is not grounded. This observation cannot be made if bats are released back into their roosts and therefore this is not recommended. If a bat cannot fly properly following tagging, the tag must be removed if possible (by cutting the fur of the bat); the aerial should be cut off the tag; and/or advice or assistance sought from a vet.

- **Radiotelemetry** – the most basic form of data required from radiotelemetry surveys is the bat identification number, its location and the date/time the location record was made.

There are two main methods for determining a bat's location using radiotelemetry. The close-approach method involves at least one ecologist with receiving equipment following an individual bat and when the ecologist considers it has reached the bat's location, a record of the time and usually 8-figure grid reference is made. In addition, this method can make observations of behaviour and the use of habitat if close contact with the bat is maintained. This is the most accurate method of pinpointing a bat's location if the bat is relatively static, but is also constrained by land access. A significant amount of time can be spent approaching the bat before it suddenly moves quickly to another area without its position being confirmed.

The other method is triangulation, and involves a minimum of two ecologists in different locations taking simultaneous bearings at regular intervals (usually between 5 and 15 minutes) from the direction of the bat's strongest signal. This method is good for tracking multiple bats over a small area and where access to land is not possible. The accuracy of this method depends on how close the two ecologists are to the bat and their position in relation to each other and the bat. If the ecologists are closer to the bat and the lines of strongest signal are perpendicular this will increase accuracy. Triangulating moving bats at distances over 500m can achieve no more than assignment of a 6-figure grid reference. A useful method of determining the accuracy of triangulation of tagged bats in a particular study area is to use an ecologist with a tag to act as a simulated bat, from which the accuracy of bearings and triangulation fixes can be assessed under controlled conditions.

In summary, it is advisable to use a combination of both triangulation and close approach to get the most accurate data set and maintain contact with a bat. The most effective method is for three tracking teams to be deployed, with two teams triangulating a bat's broad position and the third team pinpointing the exact location using close approach.

It should be noted that while both methods are effective at obtaining location data, it is not always a reliable method of obtaining behavioural data, in that a tracked bat may be flying in a particular location, but whether the bat is foraging or socialising can be difficult to determine.

Maintaining contact with the bat is the highest priority and, with some long-ranging and fast-flying species, this is a particularly challenging task. Where contact is lost, then searching further areas in the direction the bat was last detected and in particular using high ground will increase the probability of relocating the bat. However, it should be borne in mind that, for the majority of commercial/development-related projects, tracking must at least be able to determine when the bat is using, or not using, the proposed development site.

Some species of bat (especially tree-roosting species in closed canopy woodlands) are also known to move short distances between tree roosts during the day. Therefore it should not be assumed that the equipment is faulty if the bat appears not to be in the roost it was last located in at sunrise.

Statistical analysis of radiotelemetry data to answer questions such as 'which habitats the population prefers' and 'how much time the sample bats spend on the proposed development site', or 'what proportion of home range or core flying/foraging areas are on the proposed development site' should be a major consideration to do justice to the data obtained using these methods. Further information on these techniques is given in Section 10.4.

### 9.3.5 Complementary methods

Bat activity surveys (see Chapter 8) in foraging areas identified through radiotelemetry are a useful complementary method where resources are available, as radiotelemetry of a small number of bats does not provide a full picture of bat activity.

Roost inspection surveys (see Chapters 5 and 6) and emergence/re-entry counts (see Chapter 7) are essential to understand the population size and therefore the appropriate number of bats to mark for radiotelemetry to meet the survey objectives. Depending on the circumstances, it might be possible to undertake a population count first and then decide on the number of bats to be marked (usually for obvious and relatively permanent roosts); however, in many situations it is likely that a target bat will be captured while foraging, enabling the roost to be found and a count subsequently carried out. This count would then contribute to the decision-making process about how many more bats to tag.

### 9.3.6 Timing

For consultancy purposes, radio tagging and subsequent radiotelemetry would usually take place during the active bat season unless specific objectives for winter foraging information are required. Trapping surveys are usually carried out between May and October, as discussed in Section 9.2.6. However, trapping early or late in the active season will be constrained by environmental conditions.

The specific dates of tagging and tracking bats depends wholly on the objectives of the survey. For instance, to locate maternity roosts it is advisable to undertake tracking in May, June, July or August (subject to welfare considerations). Bats have either dispersed or are dispersing from maternity roosts by September and therefore reliable population counts are unlikely.

Tagging bats will generally be linked to trapping surveys, either at the roost or in the wider countryside. It is recommended that marked bat(s) are followed immediately after tagging to gauge behaviour (and to be confident the bat is moving around). If the bat's roost is unknown, it is also advisable to stay in contact with the bat to get a likely direction of the roost as it may return there. If possible, captured bats should be followed until dawn when they return to their roost, as some bats are harder to find once inside. It is recommended that bats are tracked from roost emergence until final return. Sometimes bats will return to their roost during the night and may not re-emerge for the rest of the night. At other times bats will make numerous flying bouts from the roost and use other roosts during the night, all of which can be essential data. Additionally, bats have been recorded having separate foraging areas used at different times of the night, an early and late night foraging territory, and so it is important for bats to be continually monitored during the period of time they would be expected to be active and away from the roost.

Tagging of heavily pregnant and early lactating bats should only be undertaken where there is an overriding reason, e.g. where it fits within a detailed sequential study of a bat species through the breeding season. For roost finding, tagging should avoid such bats. When using these techniques, bat welfare should always be the overriding priority.

### 9.3.7 Survey effort

Radio tagging and tracking surveys should be proportionate to meet the survey objectives. The tracking of one or two bats to determine habitat use and population home ranges will not be sufficiently robust. Equally, tracking more than two bats simultaneously from the same population may be unnecessary should the objective of tagging and tracking be to locate a sample of breeding roosts (although this is species-dependent).

For surveys investigating habitat use and activity patterns of breeding colonies, at least 5–10% of the (estimated) population should be marked, and for rare species up to 25% of the animals of a population if potential impacts are high. Ultimately expert opinion, the questions of the study and statistical analysis requirements should be considered to ensure the appropriate number of animals are tracked to meet the aims of the project, and balanced against the welfare of individual bats and effects on the population. Tagging more than five bats from the same roost simultaneously should be avoided (due to the risk of entanglement) and, to this end, consideration of obtaining data over the entire season and even over two seasons is required. This is especially important for detecting seasonal changes in habitat use. The same bat should not be tagged twice in the course of one year unless there is a specific reason and it is covered by a project licence. Ringing bats is usually the way to determine which bats have been previously captured. Advice on ringing can be found in Mitchell-Jones and McLeish (2004) or Natural England's guidance on trapping and marking bats (NE, 2013).

For habitat use and nightly activity patterns, bats should be tracked for a minimum of three nights post-capture, and tracking should continue on more nights if the bat's movements do not become regular/consistent. A strong indication that sufficient data has been obtained is when cumulative plots of the study animal's home ranges reaches asymptote (for further information see Kenward, 2001).

From a survey planning perspective it is recommended that at least five tracking nights (post-capture) are planned for each bat to take account of bad weather or tag failures to ensure at least three nights' data can be obtained. Although useful in understanding the tagged bat's general activity patterns and to locate roosts, data from the capture night should not be used for later analysis of habitat use as the bat may be behaving differently due to the disturbance.

If bats are being marked with the objective of finding roosts, then it is advisable to continue to monitor the bat's roost movements for the lifetime of the transmitter, which can commonly be for up to two weeks. This level of monitoring will provide useful information on other roosts in the area, including night roosts.

### 9.3.8 Weather conditions

Radio tagging is usually associated with trapping bats from either field locations or at the roost. Please refer to Sections 2.6.1 and 9.2.8 for appropriate conditions. Tracking bats with radio transmitters generally does not suffer the environmental limitations of other survey methods as the survey is wholly reliant on the behaviour and activity pattern of the bats being tracked. There are numerous examples of radio-tracked bats flying in theoretically poor weather conditions for bats, especially when breeding or mating.

### 9.3.9 Next steps

Radio tagging and tracking is usually the last in a range of methods that might be used to determine the use of a proposed development site by bats. However, where roosts are discovered through radiotelemetry, then it may be necessary to carry out roost inspection surveys (see Chapters 5 and 6) or emergence/ re-entry surveys (see Chapter 7).

Chapter 10

# Data analysis and interpretation

## 10.1 Introduction

Data collected during bat surveys requires appropriate analysis, interpretation and presentation. The type of data collected depends on the surveys that were completed and what the aims and objectives of those surveys were. Where multiple surveys are proposed, it is good practice to analyse the data from the early surveys immediately to inform the later surveys, which may need to be adjusted according to the survey results. Analysing data at the end of a suite of surveys means that such opportunities would be missed.

Some examples of how to analyse, interpret and present bat data collected for proposed development projects are presented in the following sections.

## 10.2 Bat echolocation call analysis

### 10.2.1 General

The first stage of data processing is to complete sound analysis of bat calls. Russ (2012) provides detail about bats and sound equipment, call analysis and species identification and is a useful reference guide. A little information about software and species identification is provided below.

In the reporting of acoustic bat activity surveys, bat activity is often quantified in terms of numbers of bat passes but it can also be reported in terms of number of bat pulses (Sowler and Middleton, 2013). **It is important that the criterion for determining a bat pass is the same across all recordings that will be subject to comparison and that this criterion is reported.**

It is important to acknowledge that a bat pass or a bat pulse is an index of bat activity rather than a measure of number of individuals in a population. One hundred bat passes could be from 100 bats passing the detector or one bat passing 100 times. Reality is likely to fall somewhere between the two and this is where observational data can add context. There is little evidence that higher levels of bat echolocation activity actually reflect higher bat abundance (Hayes, 2000). Bat activity indices can be more accurately described as indices of the amount of use bats make of an area, and should be used to quantify bat activity, not abundance.

The benefit of recording bat activity is that there is an auditable record of work carried out. Bat echolocation data collected during bat surveys should be stored in case this auditable record requires later scrutiny.

### 10.2.1 Software

A number of sound analysis software options are available for both manual and automated sound analysis. Some software is brand-specific and can only handle recordings from specific bat detectors; other software is generic and can be used with a wide range of bat detectors. Choice of equipment and sound analysis software is likely to depend on the volume of data collected. Manual analysis may be appropriate for a small number of echolocation calls collected during an emergence survey. However, ecologists are increasingly collecting very large data sets (many thousands of bat calls) using automated/static detectors and automated analysis may be a more effective and efficient choice to handle the large volume of data and achieve consistency across a data set and between data sets.

The limitations of any sound analysis method used should be recognised and when using manual and/or automated methods, a proportion of the resulting data should always be verified for quality assurance purposes. A good approach with automated techniques is to at least verify all non-*Pipistrellus* calls manually and seek peer review where calls appear to be from rarer species, particularly if the site is outside their known range.

Regardless of the detecting equipment and software used, it is essential that an ecologist has the appropriate knowledge and experience to use it or results could be impaired.

### 10.2.3 Species identification

Bat call identification is difficult, even in the UK where there is a limited range of species. Some species, such as the greater and lesser horseshoe bats, can be identified with certainty from a spectrogram due to their unique call characteristics. Other species, for example a whiskered bat, can only be identified with a low degree of confidence to the species level but can be identified with a higher degree of confidence to its genus, *Myotis*.

The complexity involved in identifying bat calls is compounded by variability within the calls used by different species of bats. All species of bat vary the characteristics of their calls (e.g. frequency, call duration, inter-pulse interval) within a given range that is typical of the species. However, there is often a substantial degree of overlap for some or all characteristics between species. Calls are adapted dependent on behaviour (e.g. commuting, searching or approaching prey) and the surrounding habitat (e.g. in open or closed habitats or enclosed spaces) (see, for example, Holderied *et al.*, 2006; Murray *et al.*, 2001).

In addition to echolocation calls, bats also employ a wide range of social calls, which can be used to aid identification of bat species and to interpret their behaviour. More on interpreting social calls can be found in Middleton *et al.* (2014).

The quality of recorded calls will also depend on the location of the bat detector and the orientation of the bat to the microphone. If a detector is deployed on a hedge and a bat is flying over the hedge or behind the hedge the quality of the recorded call is likely to be lower than if the bat is echolocating directly at the microphone with no obstacles between the two to impede the passage of sound. Frequency has a big effect on how far away a call can be detected: lower-frequency calls can be detected from further away than higher-frequency calls. Most detectors will record bat calls at optimum quality (and at greater distances) if the call is received by the microphone in the same line as the long dimension of the microphone (on axis), although this is less important for omnidirectional microphones.

A proportion of bat species cannot be identified with certainty from their echolocation calls (sometimes due to the quality of the call but also because of the overlap in call characteristics between species) and it is important to consider and document how bats have been identified, either as single species or to genus (e.g. *Myotis*) or group (e.g. *Nyctalus/Eptesicus* or *Myotis/Plecotus*) and what level of confidence can be applied to identification. Automated sound analysis systems provide a level of confidence. Sometimes calls recorded are of insufficient quality to identify to any level and may be categorised as unknown bat calls.

When reporting results, it is always important to remember that different species vary in the likelihood of detection using bat detectors (Fenton, 1970) and it is therefore not relevant to compare numbers of bat passes/pulses from different species.

Because of the complexities outlined above, ecologists carrying out sound analysis should have a thorough understanding of how bat echolocation works and how call parameters can vary or the accuracy of the sound analysis could be impaired.

## 10.3 Analysis of bat activity survey data

Most types of bat surveys do not require statistical analysis. This section applies primarily to data collected during static/automated bat detector surveys (see Section 8.2). Statistical testing can be applied to other types of surveys (indeed, an example is given in Appendix 8), but it is only essential where large amounts of data are generated as it is otherwise difficult to extract meaning from the results. Analysis increases our understanding of the significance of differences in species composition and activity levels both spatially and temporally, which facilitates a more effective impact assessment. Statistics can be used to organise, summarise and describe the quantifiable data and can help to draw inferences in a transparent and authoritative way. The consequences of not undertaking formal statistical analyses are that some of the conclusions drawn from the data could be describing random 'noise' rather than something of statistical significance.

Data analysis is an iterative process by which data collected during field surveys and generated through the analysis of sound files recorded by bat detectors becomes knowledge and insight. The collation of data will involve cleaning the information for input errors, outliers, mistyping and highlighting missing values; for a protocol on how to achieve this, see Zuur *et al.* (2010).

Following data collation, a circular process of data transformation, visualisation and modelling takes place, as follows:

- **Transformation** is when data is manipulated and/or aggregated, creating new variables. One example of this is standardising bat activity observed per night through the season (with different night-time lengths) to activity per hour.
- **Visualisation** offers awareness of patterns within the data and uncovers the unexpected. However, it does not provide a scale to measure against, i.e. it does not clarify whether the differences in the data are random or significant.
- **Modelling** is where hypotheses are tested with statistical procedures (although some modelling techniques may not explicitly include hypotheses) to provide a scale to measure against, i.e. inference can be made about whether the differences in the data are random or significant.

Although data exploration is a key part of any analysis, it is recommended that it is clearly separated from hypothesis testing. It is good practice to decide what statistical tests to apply during the survey design (or after a 'pilot study' or initial survey), i.e. they should be decided **before the surveys** based on the ecologist's understanding of the questions being asked and their biological understanding of the system. Data analysis should be viewed as an aid to the decision-making process that has followed through from the objective of the survey and survey design (Underwood, 1997) (see Section 2.2.6).

Table 10.1 names some statistical tests that can be applied to bat survey data. The tests listed are robust in that the observed data can be used as it comes, and no assumption is made about the distribution of the data; all the tests are what are termed non-parametric. There are some minimum requirements, which are detailed in Table 10.1.

Before using any of the statistical tests it is recommended that you refer to a reference that gives a background on how to apply the test and its limitations. There are many other statistical procedures that can be applied to ecological data; Dytham (2011) provides an introductory text and Legendre and Legendre (2012) provide more detail.

The statistical tests listed look for differences and/or relationships and are helpful in interpreting bat survey data for reporting; the tests are useful in separating the signal from the noise. There are simple tests to look at the differences for individual species and multivariate tests that allow for the comparison of communities (e.g. the assemblage of bats) from species 'abundance' data. These tests also allow for ecological data to be explored against environmental factors. All the statistical tests add weight to professional opinion.

**Table 10.1 Statistical tests that can be applied to bat survey data.**

| Example application of data analysis | Statistical test |
|---|---|
| Compare two samples of bat activity (expressed as bat passes per night for an individual species or groups of species). | Non-parametric tests that look at the differences for individual species (see Dytham, 2011). |
| For example, bat activity observed at one location over several nights in June (sample 1) compared with activity observed at the same location over several nights in July (sample 2). These data are unpaired. | Mann–Whitney U test: (for unpaired data) [the number of nights in each sample can be different; see Fowler *et al.*, 1998]. |
| OR bat activity observed at two locations, such as a hedge (sample 1) and an open field (sample 2) over several nights. These data are paired. | Wilcoxon's signed rank test: (for paired data) [the number of matched pairs whose difference is not zero should be six or more; see Fowler *et al.*, 1998]. |
| Compare *three or more samples* of bat activity (expressed as bat passes per night for an individual species or groups of species). | Non-parametric test that looks at the differences for individual species (see Dytham, 2011). |
| For example, bat activity observed at one location over several nights in each of June (sample 1), July (sample 2), August (sample 3) and September (sample 4). | Kruskal–Wallis test: [if there are only three samples then there must be at least five nights in each sample; see Fowler *et al.*, 1998]. |
| OR bat activity observed at three or more locations (each one is a sample) over several nights in only one month. | As above. |
| Test *three or more samples* of bat activity for whether the order of the samples is meaningful; is there a decreasing or increasing trend (data expressed as bat passes per night for an individual species or groups of species)? | Non-parametric test that looks at trends in individual species (see Field *et al.*, 2012). |
| For example, bat activity observed at one location over several years 2010, 2011, 2012, 2013, 2014. | Jonckheere–Terpstra test: [this is similar to the Kruskal–Wallis test but looks for information about whether the order of the samples or groups is meaningful – so it can test for a decreasing or increasing trend]. |

The skill and resources required for managing data and undertaking data analysis should not be underestimated. Bat survey projects can be undertaken over many years and it is not uncommon for the project team to change during this time; it is therefore good practice to manage information so others can understand and have access to what has been done. This requires the management and analysis of data to be transparent and reproducible by others. There are software tools that make the process of data management, analysis and reporting reproducible; many of the software tools to undertake this are open source and available for all to use (see Box 6).

**Box 6 Tools for data management, analysis and reproducible reporting.**

Data management: Excel® (https://products.office.com/en-gb/excel) and its Open Office (https://www.openoffice.org/) equivalent is a useful data management tool.

Data analysis: a powerful open source statistical software environment is available with R (https://cran.r-project.org/). Commercially available data analysis software includes SPSS (http://www-01.ibm.com/software/uk/analytics/spss/); Minitab (http://www.minitab.com/); SAS (http://www.sas.com/); STATA (http://www.stata.com/) and software aimed at biologists and ecologists Primer-E (http://www.primer-e.com/).

Reproducible reporting: the open source Integrated Development Environment (IDE) RStudio™ (https://www.rstudio.com/) with its implementation of R and RMarkdown (http://rmarkdown.rstudio.com/) enables ecologists to gather data (from Excel or Open Office) and visualise and run statistical analyses. Through RStudio™ you can connect the R-based analysis dynamically and reproducibly to presentations and reports; created in mark-up languages such as Markdown and LaTeX (http://www.latex-project.org/). Directly linking your data, your analyses, and your results, a process called literate programming (Knuth, 1984), makes tracing your steps much easier.

Appendix 7 gives an introduction to data analysis, describing some simple transformation, visualisation and modelling of data and some worked examples are provided in Appendix 8. The modelling/analysis described is mostly non-parametric, which makes fewer assumptions about the data, is simple to apply and is suited to analysing the large and small samples that are frequently found with ecological data. All of the examples provided in Appendix 7 and Appendix 8 have been created in R.

## 10.4 Analysis of bat radiotelemetry survey data

This section applies primarily to data collected during radiotelemetry surveys (see Section 9.3). For a detailed account of radiotelemetry and analyses of radiotelemetry data please see Kenward (2001). Some of the common analysis techniques associated with radiotelemetry and bats are given below.

Establishing home ranges is particularly useful in understanding the extent of use of a proposed development site in relation to the surrounding landscape. This is usually an area-based calculation determined after tracking the bat for a period of time that establishes a regular pattern of activity. From home range calculations, it may be possible to determine what proportion of the home range of the bat or colony the proposed development site is likely to comprise.

Bats often move through large areas to spend time foraging or socialising in smaller 'core' areas. It is often important to quantify these core areas, as overall home ranges do not necessarily determine the 'important' areas/habitats that are used by the bat.

There are a number of methods for estimating the home ranges and core areas of bats. The common methods are minimum convex polygons (MCP), cluster analysis and kernel contours. Kenward (2001) provides detail on all the main methods. However, it should be noted that the selection of the home range estimation tool should be appropriate for the behaviour of the bat. Some bats (e.g. Bechstein's bat) may make small movements from roost to foraging areas and the selection of kernel contours might be appropriate, whereas for fast-moving bats that use discrete foraging sites scattered across the landscape, the use of cluster analysis and MCPs would be more appropriate.

For studies that are seeking to determine habitat preferences of the bats affected by a development proposal, it is important to use statistical techniques to quantify and establish such preferences. A common method of analysis of habitat selection is to compare the proportion of habitats used by the bats the majority of the time (i.e. core areas) to the habitats that were available to the bat within its home range (MCP). Habitat selection of areas used versus available can be determined through the use of statistical tests such as the compositional analysis methods developed by Aebischer *et al.* (1993). To be reliable, these methods require an understanding of where each bat was located for a significant proportion of each night tracked, and is more difficult for fast-moving bats.

It is also important that appropriate habitat data is collected covering the areas available to the bat (e.g. the MCP) (see Section 9.3.7 on survey effort).

Chapter 11

# Writing bat reports

## 11.1 Introduction

It is essential that bat survey reports are accurate, clear, concise and, most importantly, serve the purpose for which they were intended. A survey report for the purposes of these guidelines is reporting on what is there and may be making recommendations for action. A monitoring report is reporting on what action has been taken, whether it has been implemented correctly and whether it has been effective. Reporting on monitoring is not covered by these guidelines.

This chapter covers the essentials of good bat survey report writing and provides a standardised template for a bat survey report. Information can also be found in *Guidelines for Ecological Report Writing* (CIEEM, 2015).

Put simply, a bat survey submitted in support of a development proposal should show:

- what is there and its value and significance;
- how it will be impacted by the development;
- how these impacts can be mitigated;
- how the development will result in no net loss (and where possible a net gain – particularly for planning purposes) to their population.

In general, professional reports should:

- be accessible to the intended audience;
- use clear and simple sentence structures;
- be proofread for grammar, spelling and punctuation;
- list both scientific and common names of species;
- cite appropriate references to back up assertions;
- use a standard, consistent format for references;
- leave no room for misinterpretation; and
- propose clear, definitively stated actions resulting from the findings of the report.

## 11.2 Standard template for bat survey reports

Box 7 provides guidelines on the content of individual sections of a bat survey report produced in relation to planning and development. It may be possible to streamline the process of report writing by producing reports that are fit for multiple purposes. Not all sections are relevant in all situations; professional judgement should be used in determining the final format.

**Box 7 Sections and content relevant to bat survey reports for planning and development.**

Title page

- Concise title explaining the type of survey, the subject of the survey and the location, e.g. 'Preliminary Roost Assessment of Barn at Brook Farm'.
- The date and version number of the report.
- The client's name and/or organisation.
- The author's name and/or organisation.
- Other relevant information such as 'draft' or 'confidential'.

Executive summary

- A non-technical, concise summary of the whole report including the purpose of the report, the site context, survey methods, survey results, limitations and methods to overcome limitations, further survey recommendations, impact assessment, methods to avoid, mitigate or compensate, enhancement measures, post-construction monitoring measures and conclusions as appropriate. This should be self-contained and may not be needed if the report itself is very short.

Contents page

- List of sections including numbers, titles and page numbers.
- List of all figures, tables, graphs and photographs including numbers, titles and page numbers.

Introduction

- Purpose/context of the report: written by whom, for whom and why.
- Proposed development activities, including future use of site. If not known, this should be stated.
- Site context – size, brief description, brief description of habitat, locational information (description, grid reference, postcode), map showing site boundary, aerial photographs, photographs.

- Brief description of surveys carried out including aims and objectives.
- Reference to other reports or information available prior to the surveys being carried out, e.g. preliminary ecological appraisal or reports from other ecologists.

Methods

- Desk study: a list of organisations and sources from which designated sites and bat records were requested and obtained, how the search area was specified; the date that the search was made; reasons for not carrying out a data search if relevant.
- For each type of bat survey carried out and for each separate survey occasion (where relevant):
    - bat survey types used;
    - equipment/software used;
    - description of method (including how bat pass was defined and parameters used for echolocation analysis);
    - justification for choice of method and equipment (linking to aims and objectives) including any deviation from good practice (reference these guidelines) and rationale;
    - how the design of the survey was informed by previous surveys (or by the desk study);
    - number of ecologists;
    - ecologist names;
    - relevant ecologist training, experience, licences and licence numbers;
    - area surveyed with justification for choice of survey area and maps/aerial photographs for reference;
    - all ecologist and equipment locations (e.g. emergence/dawn ecologist locations, transect routes, static survey locations using automated detectors, location of mist nets and harp traps) for each separate survey, with justification for choice of locations and maps/aerial photographs for reference;
    - survey dates;
    - survey start and end times;
    - sunset/sunrise times;
    - limitations of survey methods (e.g. weather, access, timing, health and safety considerations) or equipment.

Results

- Preliminary ecological appraisal – desk study: a list of sites designated for their bat interest plus descriptions and a summary of bat species and roosts in the area, with a map if available/relevant/possible (the amount of detail provided will depend on the terms and conditions of the data provider).
- Preliminary ecological appraisal – fieldwork: a Phase 1 map with target notes describing and assessing suitability of features for roosting, foraging and commuting bats; a set of photographs of the site.
- Preliminary roost assessment of structures and winter hibernation surveys:
    - descriptions of structures surveyed (including reference number, location, type of building/structure, dimensions, age, construction materials, current use);
    - descriptions of potential and actual access points and roosting places (including height above ground level and aspect);
    - descriptions of evidence of bats found;
    - results of DNA analysis undertaken;
    - description of areas not surveyed and reasons why;
    - all of the above marked onto a plan of the site;
    - a set of cross-referenced photographs highlighting key features.
- Preliminary ground level roost assessment of trees:
    - descriptions of trees surveyed (including reference number, species, diameter at breast height);
    - descriptions of potential and actual roost features (including height above ground level and aspect);
    - description of evidence of bats found;
    - trees not surveyed and reasons why;
    - all of the above marked onto a plan of the site;
    - a set of cross-referenced photographs.
- PRF inspection survey – trees
    - description of potential and actual roost features surveyed (including dimensions, level of protection from elements);
    - description of evidence of bats found;
    - features not surveyed and reasons why;
    - all of the above marked onto a plan of the site;
    - a set of cross-referenced photographs.
- Presence/absence and roost characterisation surveys:
    - descriptions of emerging/returning bats (including time, species, number, exit/entry point, behaviour observed);
    - descriptions of other notable bat behaviour (including internal flight, observations of major commuting routes locally);
    - all of the above marked onto a plan of the site.
- Bat activity surveys:
    - tables of bats recorded/observed (including time, species, number of passes, behaviour observed) where low numbers or this information summarised where higher numbers recorded;
    - the above information summarised on an annotated plan or aerial photograph of the site.

- ALBST (minimum data required):
  - tables of bats captured in relation to trap locations (including time/date, species, age class, breeding status and any other data collected);
  - tables of radio-tracked bat summary data to include tracking dates, number of nights tracked, number of fixes obtained for each bat, home range size and maximum distance from roost.

Evaluation
- Data visualisation, analysis and interpretation of the results. This section is particularly important because it links the results of the surveys with the impact assessment and subsequent recommendations. There should be enough information to make this link explicit.
- Limitations of survey (with respect to weather, survey methods, timing, equipment, detectability of different species, etc.) and impacts on survey results.
- Relevant European and UK legislation, relevant national and local planning policy, national and local bat species biodiversity action plans. Place the findings of the survey into a legal and policy context.

Impact assessment
- Assessment of the impacts of the proposed development pre- and during construction and during operation and decommissioning (where relevant) on designated sites, roosts and commuting and foraging areas used by bats.

Required actions
- Further surveys – exact requirements described.
- Justification on the necessity or otherwise for an EPS licence to be obtained.
- Avoidance, mitigation, compensation and enhancement measures. All measures should be quantified, definitively stated, marked onto diagrams and drawn up in consultation with the client. Language such as 'should' and 'could' must not be used to describe a required measure. Instead, use 'will', as long as this has been agreed with a client (this may not be possible in early iterations of a series of reports). This enables planners to impose clear, enforceable conditions relating to this section of the report.
- Post-construction monitoring. See comments above on enforceability and use of language.

References
Glossary or definition of terms.

Appendices
- Should include supplementary or supporting material that would interrupt the flow of the main report. May include maps, aerial photographs, GIS files (which can be useful for large and complex schemes), figures, photographs and background/raw data.

## 11.3 Use of illustrative material

The importance of illustrative material in reports should not be underestimated. A report should convey the required information in the most concise and easy to understand format – an annotated map, aerial photograph, diagram, graph, figure or photograph can replace many words. Examples of how to visualise data are provided in Appendix 7 and Appendix 8.

## 11.4 Other considerations

### 11.4.1 Peer reviewing

Professional reports should not be sent out without a peer review, generally by a more senior or experienced colleague. This identifies any errors with grammar, spelling and punctuation but also ensures that the content is appropriate for the audience and the recommendations are clear and justified. Many consultancies have a good practice system for signing off reports where the author and the reviewer are identified and signatures are required for final approval and submission.

### 11.4.2 Submission of bat records

It is good practice for ecologists to state in their terms and conditions that records from surveys will be submitted to record-holding organisations. Bat records can then be submitted to Local Records Centres, LBGs or the NBN.[46]

In Northern Ireland the ecologist has a choice of who they submit their data to:

1. Northern Ireland Bat Group; **OR**
2. Centre for Environmental Data and Recording (CEDaR), which is Northern Ireland's Local Record Centre; **OR**
3. National Biodiversity Data Centre (NBDC) in the Republic of Ireland that hosts the 'Atlas of Irish Mammals' for both Irish jurisdictions and shares all relevant records with CEDaR (above).

This practice should be encouraged, for the benefit of all stakeholders, and only waived in exceptional circumstances where there is genuine justification.

[46] http://www.searchnbn.net

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# Appendix 1. Equipment table

**Table A1.1 Equipment relevant to different survey types.**

| Equipment | Preliminary ecological appraisals – fieldwork | Preliminary roost assessment – structures | Presence/absence survey (structures) | Roost characterisation survey (structures) | Winter hibernation survey | Preliminary ground level roost assessment – trees | Presence/absence survey of trees using PRF inspection | Presence/absence survey of trees using dusk/dawn visits | Roost characterisation survey – trees | Bat activity survey (manual) | Bat activity survey (automated/static) | Swarming survey (acoustic) | Back-tracking survey | Trapping survey (hand net) | Trapping survey (harp trap or mist net) | Radio-tagging/radio-tracking survey |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binoculars. | ✔ | ✔ | | | ✔ | ✔ | | | | | | | | | | |
| Powerful torch. Preferably non-heat-producing, e.g. LED lamp, particularly in potential hibernation situations. With filter if appropriate. More information on licensing for the use of artificial lights is provided in Section 1.2.2. | ✔ | ✔ | | | ✔ | ✔ | ✔ | | | | | | | | ✔ | |
| Headtorch. Plus spare handy in pocket for extracting bats from traps if trapping. | | ✔ | ✔ | ✔ | ✔ | | | ✔ | ✔ | ✔ | ✔ | | ✔ | ✔ | ✔ | ✔ |
| Small torch. | | ✔ | | | ✔ | | ✔ | | | | | | | | | |
| Caving helmet and lamp. | | ✔ | | | ✔ | | | | | | | | | | | |
| Extendable mirror. | | ✔ | | | ✔ | | ✔ | | | | | | | | | |
| Ladder. For safe access to a suitable working platform. Follow HSE recommendations on checking/documentation and safe use. Where safe access to a suitable working platform is not available consider alternatives such as the use of a cherry picker, MEWP or scaffold tower. | | ✔ | | | ✔ | | ✔ | | | | | | | | | |
| Compass. | ✔ | ✔ | | | ✔ | ✔ | ✔ | | | ✔ | ✔ | | ✔ | | | ✔ |
| Tape measure or laser range finder. | | ✔ | | | ✔ | | | | | | | | | | | |
| Clinometer. | | ✔ | | | ✔ | ✔ | | | | | | | | | | |
| Temperature/humidity logger. | | | | ✔ | ✔ | | | | | | ✔ | ✔ | | | | |
| Weather station to record wind and precipitation if required. | | | | | | | | | | | ✔ | ✔ | | | | |
| Endoscope. More information on licensing for the use of endoscopes in England is provided in Section 1.2.2. | | ✔ | | | ✔ | | ✔ | | | | | | | | | |
| Collection pots with labels and disposable gloves. | | ✔ | | | ✔ | ✔ | ✔ | | | | | | | | | |
| Bat handling gloves gloves. (Different types for different-sized species.) | | ✔ | | ✔ | | | | | | | | | | ✔ | ✔ | ✔ |
| Hand-held bat detector and recorder. Heterodyne bat detectors are not acceptable for commercial surveys. | ✔ | ✔ | ✔ | ✔ | | ✔ | ✔ | ✔ | ✔ | ✔ | | | ✔ | ✔ | ✔ | ✔ |
| Counter. | | | ✔ | ✔ | | | | ✔ | ✔ | | | | | | | |
| Hand-held radios. | | | ✔ | ✔ | | | | ✔ | ✔ | ✔ | | | ✔ | ✔ | ✔ | ✔ |
| Night-vision scopes or infrared or thermal imaging camera. | | | ✔ | ✔ | | | | ✔ | ✔ | | | | | | | |
| Automated bat detector. | | | ✔ | ✔ | | | | | | | ✔ | ✔ | | | | |
| GPS. | ✔ | | | | | ✔ | | | | ✔ | | | ✔ | ✔ | ✔ | ✔ |
| Tree tape (logger's tape). | | | | | | ✔ | | | | | | | | | | |
| Tree tags, nails and a hammer. | | | | | | ✔ | | | | | | | | | | |
| Rope access equipment such as harnesses, ropes, carabiners, prussic loops, strops, climbing helmet etc. (or access equipment such as cherry pickers, MEWPs or scaffold towers). | | | | | | | ✔ | | | | | | | | | |

**Continued: Table A1.1 Equipment relevant to different survey types.**

| Equipment | Preliminary ecological appraisals - fieldwork | Preliminary roost assessment - structures | Presence/absence survey (structures) | Roost characterisation survey (structures) | Winter hibernation survey | Preliminary ground level roost assessment - trees | Presence/absence survey of trees using PRF inspection | Presence/absence survey of trees using dusk/dawn visits | Roost characterisation survey - trees | Bat activity survey (manual) | Bat activity survey (automated/static) | Swarming survey (acoustic) | Back-tracking survey | Trapping survey (hand net) | Trapping survey (harp trap or mist net) | Radio-tagging/radio-tracking survey |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Robust kit bag. | | | | | | | ✓ | | | | | | | | | |
| Hand net. More information on licensing for the use of capture is provided in Section 1.2.2. | | | | ✓ | | | | | ✓ | | | | | | | |
| Thermometer. | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Fine scissors to cut nets if needed. | | | | | | | | | | | | | | | ✓ | |
| Callipers. | | | | ✓ | | | | | ✓ | | | | | ✓ | ✓ | ✓ |
| Bat holding bags. Drawstring to be tied firmly to prevent bat escape. Bags should be hung up rather than laid on the ground. Wash bags regularly and ensure no loose threads are present that may entangle bats inside the bag. | | | | | | | | | | | | | | ✓ | ✓ | ✓ |
| Mist nets*, poles, pegs and guy lines. More information on licensing for the use of mist nets in England is provided in Section 1.2.2 | | | | | | | | | | | | | | | ✓ | ✓ |
| Harp traps*, guy lines and possibly, ropes. More information on licensing for the use of harp traps in England is provided in Section 1.2.2 | | | | | | | | | | | | | | | ✓ | ✓ |
| Acoustic lures*. More information on licensing for the use of acoustic lures in England is provided in Section 1.2.2 | | | | | | | | | | | | | | | ✓ | |
| Glue. Surgical or colostomy latex glues are generally safe to use for tagging bats and are temporary. | | | | | | | | | | | | | | | | ✓ |
| Small brush or cotton bud to apply glue. | | | | | | | | | | | | | | | | ✓ |
| Curved scissors. To cut bat fur for tagging (unless possible to part hair). | | | | | | | | | | | | | | | | ✓ |
| Weighing scales. | | | | | | | | | | | | | | | | ✓ |
| Portable soldering iron and solder. To solder (and start) the contacts some types of radio transmitters. Operate on gas, ensure adequate supplies | | | | | | | | | | | | | | | | ✓ |
| Radio transmitters**. VHF radio transmitters are small enough to fix safely to a bat without affecting its welfare to enable tracking. If several bats are being tracked simultaneously frequencies should be well spaced. | | | | | | | | | | | | | | | | ✓ |
| Receivers (and headphones**). Scanning receivers can aid the tracking of multiple bats simultaneously. | | | | | | | | | | | | | | | | ✓ |
| Antennae. To receive radio transmitter signals/pulses**. Antennae usually need to be tuned to appropriate bandwidth. Two types - low-range omni-directional element useful for vehicle searches of lost bats. Directional Yagi type can be three- or five-element. Five-element Yagi provide the best range and more accurate direction fixes. | | | | | | | | | | | | | | | | ✓ |

*See Appendix 5 for more information on mist nets, harp traps and lures.
**See Appendix 6 for more information on radio transmitters, receivers/antennae.
Note: The equipment chosen for a survey should make the survey safer, easier, more efficient and more thorough. Requirements for equipment depend on the nature of the survey and nature of the site, therefore this list should be adapted accordingly. As with all equipment, manufacturer's instructions should be adhered to and training/experience may be necessary to ensure safe and effective use.

# Appendix 2. Background information on bat detectors

The three main systems for converting ultrasound produced by bats into sound that we can hear are **heterodyne**, **frequency division** and **time expansion**. In addition, **full-spectrum sampling** enables the recording of ultrasound at a high sampling rate without converting frequencies to the audible range. The last three are all 'broad-band' systems that simultaneously sample all frequencies in the bat calls, which means that all bat calls can be sampled if the sampling rate of the detector is at least double the frequency that needs to be sampled, and that recordings from these systems are suitable for sonogram analysis and bat call identification. This enables measurement of call parameters, to varying degrees of precision depending on the bat detector system used, which can help to confirm species identity. Professional surveys should only be carried out using broad-band detectors.

## Heterodyne

In a simple heterodyne system, ultrasound is picked up by the microphone and mixed with a signal from a tuneable oscillator in the detector which the user can adjust, normally by turning a dial on the detector. The bandwidth varies between detectors and can affect how accurately the peak frequency of bat calls can be determined, because a narrow bandwidth makes it easier to discern differences in tonal quality (linked to peak frequency) when tuning. Conversely, a wider bandwidth may result in more bats being detected. Heterodyne bat detectors are not considered suitable for commercial surveys.

## Frequency division

This is normally the cheapest of the 'broad-band' systems that simultaneously monitor the full range of frequencies contained within all bat calls. A frequency division of eight, for example, refers to counting the average time spent for eight oscillations of the electrical signal (that matches the acoustic signal). The time is measured when the voltage of the transformed sound wave equals zero.[47] This measurement of time allows a calculation of the average frequency of those eight oscillations. A single (dominant) frequency is plotted for each measurement point in time, with many more frequency points recorded in full-spectrum sampling. As a result, low-amplitude bat calls will not be recorded (unlike full-spectrum recordings) if another sound source of higher amplitude is received (e.g. background noise or interference) and harmonic frequencies cannot be recorded at the same time as a higher-amplitude dominant frequency.

Sufficient frequency information is preserved using this system to enable basic sonogram analysis; recordings can be made and analysed using software that processes the recordings to give us a visual image of the sound to represent frequency against time, but not multiple frequency content and amplitude. As zero-crossing analysis only preserves a small proportion of the detail of recordable sound, it is likely that a reasonable proportion of the bat passes received by the microphone will not be recorded when data is transformed through zero-crossing analysis. This is something to assess on a site-by-site basis and revisit depending on developments in equipment.

## Time expansion

Along with full-spectrum sampling (see below), this method gives the most accurate reproduction of the bat calls. In summary, the detector digitally stores the ultrasound signal, and replays it at a slower speed. The recording retains the original signal in high resolution. When the call is replayed slowly (for example, 10 times lower in frequency), it is audible to human ears. Recently developed time-expansion units do not have recording limitations (except the size of the card), and it is now possible to listen back to time-expansion recordings while continuing to record full-spectrum data, rather than having to stop sampling to listen back to previously recorded bat calls.

## Full-spectrum sampling

In addition to time expansion and frequency division systems, detectors are available that record ultrasound in 'real time' using a high-speed data acquisition card (A/D card). A microphone is connected to the A/D card which records sound at very high sample rates, thus enabling high-frequency sounds to be recorded directly. These enable the production of high-resolution sonograms as with time expansion, but also real-time continuous monitoring as with frequency division, so you get the best features of both systems. One disadvantage is that the sounds outputted by the detector are not in the audible range, so it is not usually possible to hear what you are recording in the field, although new technology means that it is possible to record in real time while listening in heterodyne, frequency division or listening back in time expansion. Some models are designed mainly for long-term unattended monitoring while others can also be used hand-held in the field and may display 'live' real-time sonograms (although note that these can be distracting, causing the surveyor to miss visible behaviours).

[47] Most frequency division bat detectors do not measure zero-crossing points as the signal at zero is not quiet but includes background noise as well as internal electronic and microphone noise. A sensitivity threshold is set above this to avoid dominant background noise masking bat calls.

# Appendix 3. Hazards and risks

Table A3.1 Hazards and risks associated with bat survey work and methods to remove or reduce risk.

| Hazards and risks associated with fieldwork | Procedures to remove or reduce risk | Equipment to remove or reduce risk |
|---|---|---|
| Lone working. | Lone working should ideally be avoided wherever possible, unless the risks can be reduced to an acceptable level using a risk assessment process.<br>If lone working is unavoidable, a buddy system (and late working procedure if appropriate) should ensure that someone knows where each surveyor is and can raise the alarm if he or she does not return when expected. Surveyors should park so that they can drive away from a site without turning. This is useful in the dark, in case of emergency, and in case of aggression. | A mobile phone (satellite phone in remote areas), map and compass should be carried. In cases where ecologists are on the same site but working remotely a two-way radio and whistle can be useful. |
| Tiredness. | Limit the number of surveys carried out during the week (refer to: Working Time Regulations 1998), taking into consideration travel distances, type of survey, difficulty of terrain, etc. Book accommodation with late checkout time if working late/very early. Encourage staff to check into accommodation if tired rather than driving home. | |
| Bad weather. | Awareness of the weather forecast. | Clothing appropriate to the local situation. |
| Working in the dark. | Surveyors should familiarise themselves with the site during daylight hours. | Powerful torch (and spare torch, batteries and bulbs). |
| Working in confined spaces. | Confined spaces training (see Section 2.7). | Specialist equipment such as breathing apparatus, gas monitors, access tripod, winch and harnesses as appropriate to specific confined space following assessment. |
| Working underground where there may be sudden drops, changes in roof height, unstable rock, decaying fixtures. | Mine safety training (see Section 2.7). | Protective warm clothing, strong boots, helmet and helmet-mounted lamp. Ladders and/or ropes. |
| Working at height. | (Refer to Working at Height Regulations 2005).<br>Tree climbing and aerial rescue course (see Section 2.7).<br>Training in use of ladders or MEWPs as relevant. | Safe means of access, e.g. MEWPs, or ropes. |
| Working on busy roads, on railways, or on farmland with working agricultural machinery. | Highways Agency training (roads) or Personal Track Safety training (railways). If appropriate, ensure local workers know that a survey is under way. | Fluorescent or reflective jacket (appropriate to site) and other PPE as directed by client. |
| Working in derelict structures / construction sites / trees where there is risk of falling masonry or branches. | As appropriate, seek advice from a structural engineer on derelict buildings, gain a CSCS card for work on construction sites or for work on trees seek advice from an arborist. Ensure local workers know that a survey is under way. | Hard hat, fluorescent or reflective jacket, safety footwear. |
| Working near water (rivers, streams, ditches, lakes, canals, etc.). | Take care when moving around. Employ safe methods of crossing watercourses such as rivers, streams and ditches. Check flood conditions online. Work in pairs. | Life jacket (consider self-inflating type to allow for greater mobility). |

| Hazards and risks associated with fieldwork | Procedures to remove or reduce risk | Equipment to remove or reduce risk |
|---|---|---|
| Working near unfenced slurry or silage pits, ponds, grain silos and stores. | Surveyors should take due care and familiarise themselves with the site during daylight hours. | Torch or head torch. |
| Slips, trips and falls on rough ground. | Take care when moving around, ensure visibility is adequate.<br>Be aware of reduced concentration when using electronic devices. | Torch or head torch. |
| Sunburn / sunstroke. | Awareness of the weather forecast. | Sun screen, hat, long-sleeved shirt and drinking water. |
| Diseases such as Weil's disease, Lyme disease, ornithosis[48] and tetanus (e.g. from rusty barbed wire). | Awareness of diseases, e.g. surveyors should carry a Weil's disease awareness medical card and be familiar with tick identification. Tetanus inoculation. | Protective clothing. Bandages or plasters over any open cuts or wounds.<br>Ornithosis – protective dust mask and gloves. |
| Insect bites and stings (horseflies, ticks, etc.). | Understand the habitat preferences of different insects; be aware of insect behaviour; avoid obvious nests. | Insect repellent and/or barrier clothing (long sleeves and trousers, nets, etc.). Carry antihistamine if likely to react strongly to bites/stings. |
| Poisonous plants (e.g. giant hogweed). | Be able to identify these plants; don't touch them. | Wear appropriate PPE. |
| Bat bite and rabies (European Bat Lyssavirus). | All those who handle bats should be vaccinated (and regularly boosted) against rabies because of the risk of European Bat Lyssavirus.<br>Care should be taken when handling to avoid bites. Information on vaccinations and what to do if bitten is available on the GOV.UK website,[49] or by calling its Centre for Infections.[50]<br>See also the Department of Health's 'Green Book' *Immunisation Against Infectious Disease 2006* from the GOV.UK website.[51] | Appropriate gloves should be worn when handling bats (advice is available from the BCT). |
| Asbestos, fibreglass and dust. | Every non-residential building should have an Asbestos Register. Surveyors should ask to see it, particularly if the building being surveyed was built between 1950 and 1985. Asbestos should be avoided and a specialist asbestos consultant called if necessary. | Asbestos – disposable overalls and respirator.<br>Fibreglass and dust – protective dust masks (conforming to BS EN149), safety glasses and overalls. |
| Sharp objects, such as broken glass or hypodermic syringes. | Take care when moving around, ensure visibility is adequate. | Safety work boots with protective toecaps and reinforced soles, impact-grade gloves, overalls, first aid kit. |
| Land that has been sprayed. | Surveyors should ask landowners or agents whether pesticides have recently been used on land being surveyed. Many pesticides have a 'harvest interval' between spraying and harvesting; surveys should not take place until after this interval. | |

48 An infectious disease that affects birds and can affect humans and other mammals.
49 https://www.gov.uk/government/collections/rabies-risk-assessment-post-exposure-treatment-management
50 020 8200 4400
51 https://www.gov.uk/government/collections/immunisation-against-infectious-disease-the-green-book

| Hazards and risks associated with fieldwork | Procedures to remove or reduce risk | Equipment to remove or reduce risk |
|---|---|---|
| Aggressive farm animals such as guard dogs, geese, bulls and cows with calves. | Surveyors should ask landowners or agents where animals are kept, and avoid those areas if possible. | |
| Shooting, e.g. for predator control (often takes place at dusk). | Surveyors should ask landowners or agents when any shooting is likely to be taking place, and avoid surveying at those times.<br>Be aware of the potential for illegal shooting. | |
| Verbal and physical assault. | Avoid lone working; work within sight of an accompanying surveyor; park so as to be able to leave quickly. Ask for security personnel in higher-risk areas, which could be identified through contact with the police. Withdraw as soon as practicable if risk is greater than anticipated. | Fluorescent or reflective jacket.<br>Attack alarm. |

NOTE: Unsafe work should not be carried out and ecologists should stop work if a survey becomes unsafe and consider alternative approaches to minimise risks.

# Appendix 4. Protocol for bat dropping collection for DNA analysis

1. Dropping samples should be collected using clean tweezers or, if unavailable, gloves should be worn (or a sample bag turned inside out) to avoid contamination. Care should be taken to avoid breaking droppings during collection.

2. If droppings of various ages are present, those that appear most recent and most intact should be selected for analysis.

3. Where it is believed that different species are present, or droppings are present in different locations, these should be collected in separate containers and using different materials to avoid cross-contamination.

4. Although single droppings are accepted for analysis, if possible it is advisable to send at least five droppings in one sample, in case a retest is needed. However, it is also advisable for the sender to retain a few in the unlikely event of loss in transit.

5. Containers should be clean and dry, sterile if possible, but this is not essential.

6. The smallest container that will hold the sample is preferred, to avoid droppings disintegrating in transit. Ideal containers are 2.0 ml Eppendorf-type plastic tubes, or small (preferably 10 cm × 14 cm) resealable plastic bags (Ziploc or similar) are suitable. Samples can be padded with clean non-fluffy material (e.g. paper) to reduce movement in transit. Do not use glass tubes.

7. Ensure samples are labelled and packaged according to the instructions provided and that a separate note is kept by the sender of which sample numbers relate to which sample locations.

8. The sample should be dispatched to the lab as soon as possible, but if this cannot be done immediately, then it should be stored in a dry, cool place. Freezing or refrigeration is not necessary. If the sample is particularly fresh and is damp, the droppings should be air dried on a clean sheet of paper at room temperature, to help preserve the DNA and to prevent the droppings becoming squashed together in transit.

# Appendix 5. Background information on mist nets, harp traps and lures

## Mist nets

Specialist bat mist nets are manufactured by a range of suppliers and have smaller pockets compared to nets designed to catch birds, although this type of net can also be used. Nets come in a range of sizes, from 2m to 25m in length and 2 to 3m in height, and usually 36mm mesh. Net selection will depend on the habitat. For mist netting in closed woodlands, 6 × 2.6m nets are usually more than adequate when used in combination with an acoustic lure. Shorter nets would be more appropriate for tunnel entrances and, for more open woodlands, 9 to 18m nets can be used effectively. The height of the mist net is governed by the habitat being surveyed, and limited by pole lengths. Guy lines and pegs are also required to stabilise the net. Specialist mist nets such as canopy net systems are also available where it is necessary to work at these heights. However, the advantage of using an acoustic lure is that bats that usually occupy this habitat zone can be drawn to the traps. The main advantage of using mist nets is that the equipment is relatively lightweight and inexpensive; the trapping area is also higher than for harp traps. The main disadvantage of mist nets is that bat extraction is more difficult and thus more risky to the bat's welfare. This in turn requires greater levels of skill and training to be able to use this equipment safety and effectively. In addition nets are required to be continually monitored to limit the amount of time bats are in the net.

## Harp traps

Harp traps are generally more limited in size than mist nets (usually no larger than 4m$^2$). They are also more expensive and are relatively heavy items of equipment, which is an important consideration when planning the appropriate size of the team. However, their main advantage is that once captured, bats are held in relative safety and the process of collecting bats from a harp trap is less stressful for the bat and safer for the ecologist. Therefore ecologists need less training than those using mist nets. In addition harp traps do not need continuous monitoring and can be checked every 15 minutes or sometimes even less frequently, subject to licensing guidance and/or requirements, weather conditions and time of year.

## Acoustic lures

Acoustic lures are devices or systems that emit recorded or synthesised social and echolocation calls of bats. Used in combination with mist nets or harp traps, acoustic lures can increase capture rates of bats significantly. Some devices are single unit and compact with built-in amplifiers and sequencers emitting synthesised calls and/or previously recorded calls of bats with either built-in or connected ultrasonic speakers. This makes them portable and easier to manage in the field and protect from the elements. Other systems include the combined use of laptop computers, high-speed sampling devices, amplifiers and ultrasonic speakers to emit recorded bat calls. The laptop-based system provides a flexible platform to alter and change calls in the field; however, the levels of equipment involved often require constant attention and exacerbate the logistical challenges. Common to all systems is that they are expensive. The use of spinning devices can increase the effectiveness of ultrasonic calls emitted by a static speaker by reflecting the highly directional ultrasonic calls in different directions, adding Doppler shift into the call and simulating a moving bat. However, the construction of these needs careful consideration to ensure that any bat that may come into contact with it cannot be injured by the mechanism.

# Appendix 6. Background information on radio transmitters and receivers/antennae

Radio transmitters (tags) are the key component of a radiotelemetry system. The weight of the tag should not exceed 5% of the body weight of the bat. Lighter tags usually result in a reduction of power and lifetime of the transmitters. Depending on the configuration, the majority of bat tags generally have a life of between 7 and 25 days and at ground level a range of 1–3km when the bat is outside its roost. The range of transmitters is considerably reduced when a bat is within its roost. Transmitters can be configured in three ways by tag suppliers:

1. Transmitter antenna length can be ordered to a specified length, which should be selected depending on the size and foraging behaviour of the species or project methodology. Shorter antennae (10–15cm) reduce range but are less likely to be tangled with the antennae of other bats. These are recommended for use with smaller and close commuting species and when many bats are being tagged simultaneously. Longer antennae (15–25cm) are best used with further-ranging species and very small numbers of bats, such as when the priority is to find roosts.

2. Range to battery life ratio. Suppliers of transmitters are able to increase the power of the transmitter, which increases range at the expense of battery life. Therefore if a survey only requires tracking for a week, tags can be adjusted to reduce the battery life to 7 days, and increase the transmission power to improve the detection/location range.

3. Contact connection method – two methods are generally used for UK bat species. Reed switches are contacts within the housing on the transmitter that are held apart by the use of a magnet taped to the tag. When the magnet is removed, the tag activates, and vice versa. Reed switches make starting tags a very simple exercise in the field. However, they can be less reliable than soldered contacts, and are generally heavier. Soldered contacts are more reliable but take some skill to use in the field, require extra soldering equipment, and once connected they are harder, if not impossible, to stop. An alternative method for starting tags is the 'wire loop' method, although this is less commonly used in the UK.

At least one receiver, antenna and radio transmitter is required to undertake a radiotelemetry survey. Consideration should also be given to vehicle-mounted antennae and masts to increase the effectiveness of receiving signals at range and keeping in contact with the bat. For species with known long flying ranges, such as noctule and barbastelle, vehicle-mounted antennae are usually essential and should be anticipated as part of the survey design.

# Appendix 7. Introduction to data analysis

## Transformation of data

An example of transforming data is when bat passes per night are transformed into bat passes per hour to facilitate a comparison of data collected in different months with different night lengths. This is illustrated in Appendix 8, Worked Example 3.

## Visualisation of data

**Graphical visualisation**

Graphical tools are typically used for data exploration, and to aid interpretation of the data.

A good way of comparing two or more data sets is the box plot (see Figure A7.1). The box plot visualises the median[52] and the spread of the data: the horizontal line in the box is the median, with the 25% and 75% quartiles forming a box around the median that contains half the observations. Any points outside the box are labelled outliers (outliers are retained for the analysis).The box plot in Figure A7.1 shows common and soprano pipistrelle data (1,942 records of bat passes per night) from a recent study (Mathews *et al.*, 2015). Table A7.1 gives descriptive statistics for this data set, e.g. mean, median, max, etc. These are two useful methods to summarise large data sets.

**Figure A7.1 Example of a box plot.**

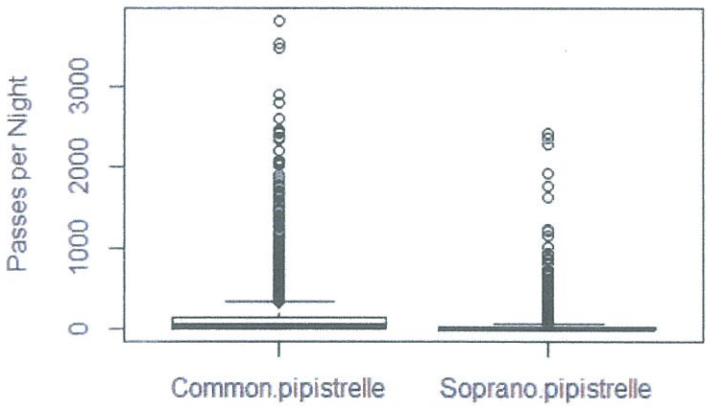



**Table A7.1 Descriptive statistics for common and soprano pipistrelle passes per night.**

| Statistic | Common pipistrelle | Soprano pipistrelle |
|---|---|---|
| Number of records/nights | 1,942 | 1,942 |
| Mean | 164.31 | 42.02 |
| Median | 37 | 5 |
| Standard deviation | 359.86 | 158.73 |
| 25% quartile | 6 | 0 |
| 75% quartile | 136 | 24 |
| Maximum | 3,815 | 2,426 |
| Minimum | 0 | 0 |

Box plots are one way of showing large data sets succinctly but, as shown in Figure A7.1, their usefulness may be limited where there is a large spread in data. Others methods of presenting data are the dot plot or Cleveland plot, the histogram and the density plot. Examples are given in Figure A7.2 to Figure A7.4; all show the same common pipistrelle data and all visually describe the distribution of bat passes recorded during the study.

**Figure A7.2 Example of a dot plot or Cleveland plot (note that this is a one-dimensional graph with the data spread vertically to facilitate visualisation).**

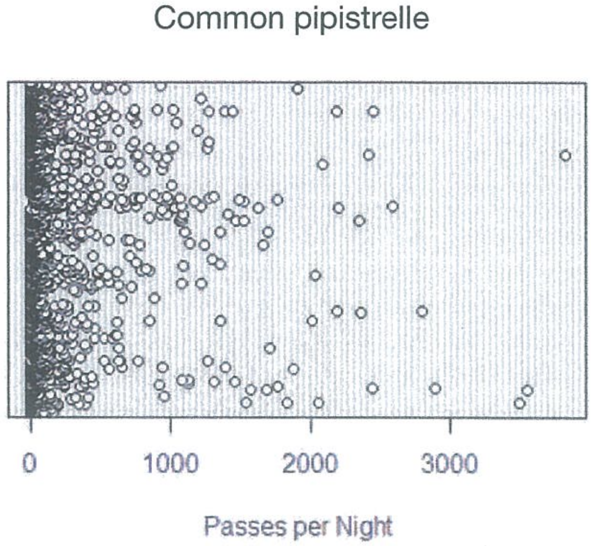
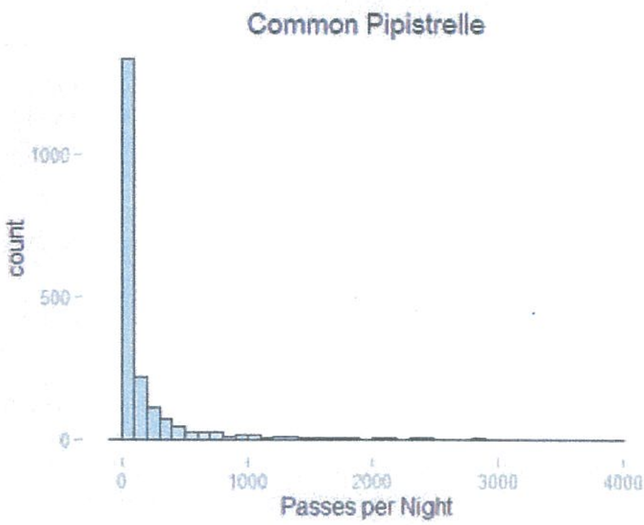
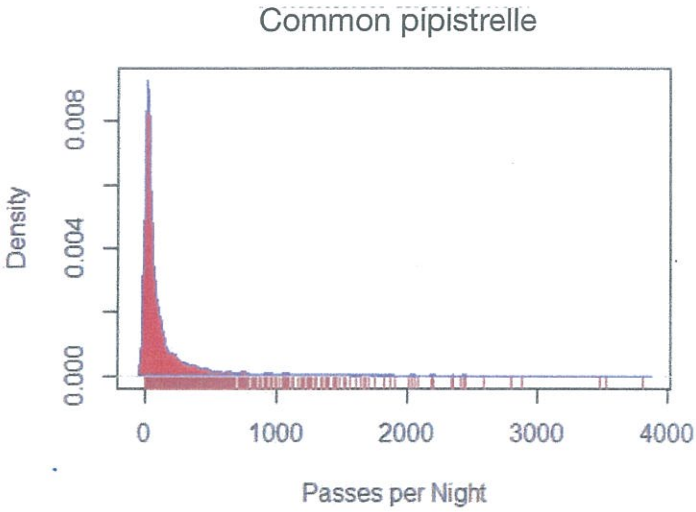



**Figure A7.3 Example of a histogram (there were over 1,000 occasions when between 0 and 100 passes per night were recorded, etc.).**




52 The value or quantity lying at the mid-point of a frequency distribution of observed values. To find the median by hand, place the numbers in value order and find the middle number; if there are two middle numbers, average them.

**Figure A7.4 Example of a density plot (similar to the histogram).**

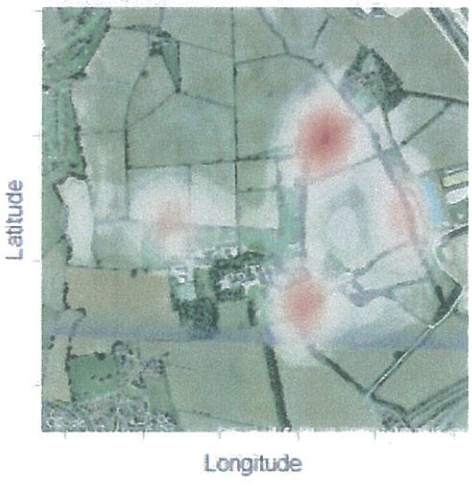



### Geographical visualisation

With the rise of GPS, commonly built into bat detectors, there is more data with latitude and longitude coordinates attached; this makes maps the intuitive way to visualise the information. The examples in Figure A7.5 and Figure A7.6 present information recorded from a transect undertaken with a bat detector that records latitude and longitude and bat activity.

**Figure A7.5 Geographic data is shown at the location where the bat was recorded and colour-coded according to species.**


**Figure A7.6 Geographic data is shown as a kernel density plot, which estimates the smoothed distribution of bat activity (Kahle and Wickham, 2013). White areas show a lower density of passes whereas red areas show a higher density of passes.**




## Visualisation of large data sets

The use of automatic bat detectors that operate for extended time periods, and identification software that can rapidly process the information, results in the collection of large amounts of data. Visualisation of the data is the primary way of communicating the information and its interpretation to others; it also helps in the analysis by showing the information in a readable form, something a table cannot always achieve. The difficult part is visualising the information without reducing any of the detail. The graphs in Figure A7.7 and Figure A7.8 present bat data recorded at six locations for five nights each month from May to September, as part of a wind farm proposal. The collision risk included is based on NE's Technical Information Note TIN051 (NE, 2012), which is being updated at the time of writing.

**Figure A7.7 Box plot showing bat data per month recorded at six locations for five nights between May and September (log scale).**

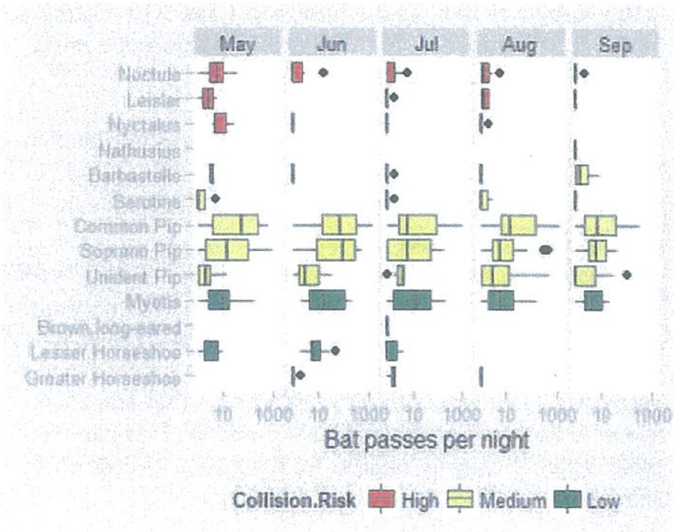



**Figure A7.8 Box plot showing bat data per site recorded for five nights each month between May and September (log scale).**

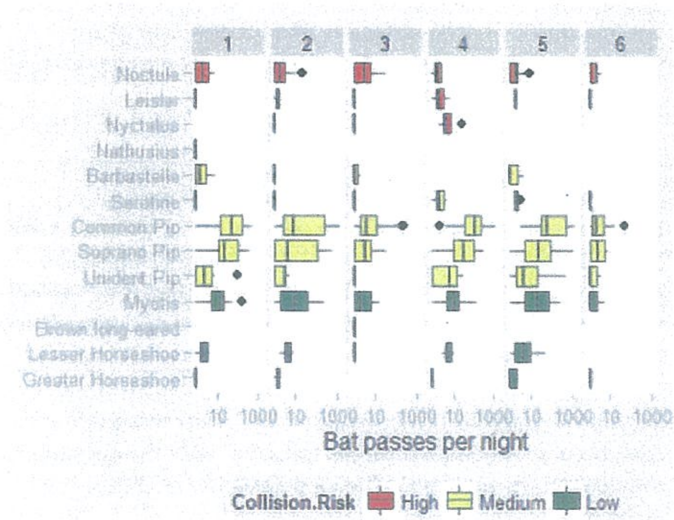
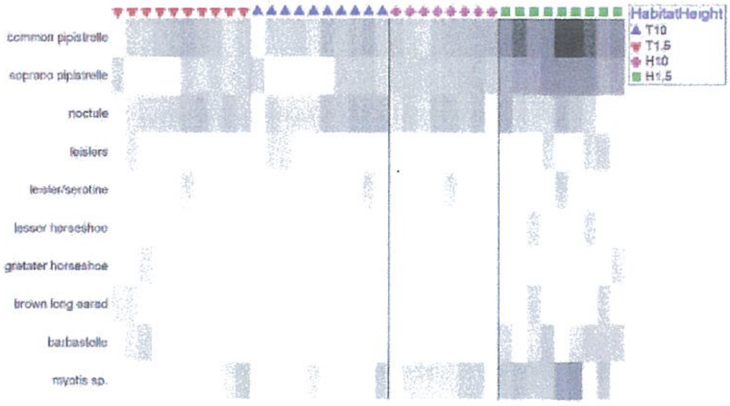


Figure A7.9 is a shaded graph that shows bats recorded for the turbine and hedge in Worked Example 2 below.

**Figure A7.9 Shade plot of turbine and hedge data.**




T10 = turbine at 10m, T1.5 = turbine at 1.5m, H10 = hedge at 10m, H1.5 = hedge at 1.5m. Darker shading indicates larger numbers of bats.

For a more comprehensive review of displaying information see Yau (2011).

## Modelling/statistical testing

Non-parametric statistical methods are mathematical procedures for statistical hypothesis testing that make no assumptions about the distribution of the variables being assessed – **the observed data can be used as it comes**. A justification for the use of non-parametric methods is simplicity. Moreover, they leave less room for improper use and misunderstanding. Non-parametric methods are frequently suitable for processing biological data (Fowler *et al*., 1998).

### Hypothesis testing

Ecologists can use **hypothesis tests** for evidence-based assessments. The idea is that a hypothesis is formalised into a statement such as 'soprano pipistrelle activity is different at the hedge and turbine', appropriate data are collected and then statistics are used to determine whether the hypothesis is true or not. For every hypothesis there will be an associated null hypothesis and most statistical tests use the null **hypothesis** as a starting point.

For the example hypothesis 'soprano pipistrelle activity is different at the hedge and turbine', the associated null hypothesis is 'soprano pipistrelle activity is *not* different at the hedge and turbine'. What a statistical test determines is the probability that the null hypothesis is true (called the *P*-value). If the probability is low then the null hypothesis is rejected and the original hypothesis accepted.

Setting a hypothesis is a good way of not over-interpreting the data, because it defines a formal question, tests the question and provides an answer from which a defendable inference can be made.

### Type I and II errors

In theory, the null hypothesis is either true or false, but only if all the individuals in a population (or a complete measure of the index) are sampled. The statistical test can only give an indication of how likely it is that the null hypothesis is true **based on the sample available**. There are two ways of making the wrong inference from the test; these two types of error, by convention, are called Type I and Type II errors, as described in Table A7.2.

**Table A7.2 How Type I and Type II errors can arise in statistical testing.**

| Null hypothesis | Accepted | Rejected |
|---|---|---|
| True | Correct | Type I error |
| False | Type II error | Correct |

In a Type I error, the null hypothesis is really true (i.e. soprano pipistrelle activity is not different at the hedge and turbine) but the statistical test has led us to believe that it is false (i.e. there are different activity levels). This type of error can be seen as a **false positive**.

In a Type II error the null hypothesis is really false (soprano pipistrelle activity is really different at the hedge and turbine) but the test has not picked up this difference. Small sample sizes will often lead to a Type II error.

### P-values

The lower the probability (*P*-value) the more confidence there is that the null hypothesis can be rejected. However, unless the whole population is measured there can never be complete certainty. It is the usual convention in biology to use a critical *P*-value of 0.05. This means that the probability of the null hypothesis being true is 0.05 (5% or 1:20). In other words, it indicates that the null hypothesis is unlikely to be true.

### Mann–Whitney U test and Kruskal–Wallis rank sum tests

Two frequently used tests include the **Mann–Whitney U test** and the **Kruskal–Wallis rank** sum test.

The Mann–Whitney U test is a non-parametric technique for comparing the medians of two unmatched samples. It may be used with as few as four observations in each sample. Because the values of observations are converted to their **ranks**, the test may be applied to a wide range of variables (e.g. ordinal or interval scales). The test is also distribution-free – it is suitable for data that are not normally distributed, for example the counts of bats above. Sample size can be unequal.

The Kruskal–Wallis rank sum test is a simple non-parametric test to compare the medians of three or more samples. It can be used to test any number of groups. This test *may* be used when there are only two samples, but the Mann–Whitney U test is more powerful for two samples and should be used in preference.

# Appendix 8. Worked examples of statistical analysis

## Worked Example 1: Turbine and hedge data

Bat surveys were undertaken at a proposed wind turbine location in SW England during the months of August and September. Four automatic bat detectors were placed for five nights in August and September at the locations shown in Figure A8.1 and Table A8.1. The survey design observes bat activity for height (1.5m and 10m) and habitat (hedge and turbine); these are all sampled equally for five nights each month.

**Figure A8.1 Survey design to sample at two heights and in two habitats at a proposed wind farm site.**

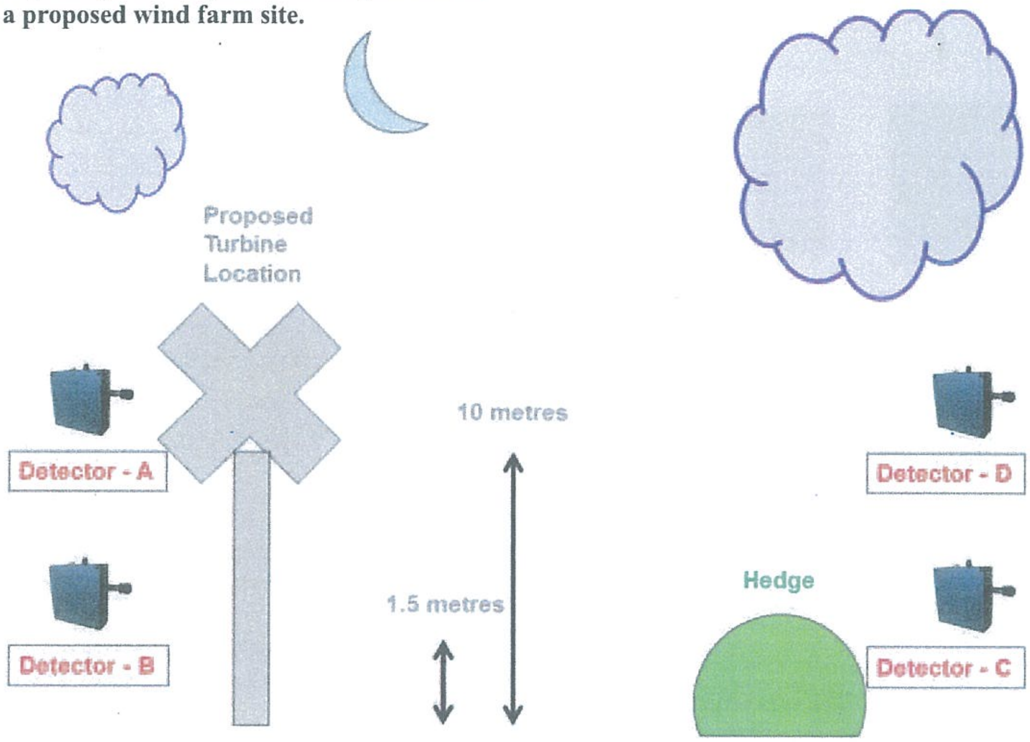



**Table A8.1 Bat detector locations in relation to survey design in Figure A8.1.**

| Bat detector | Height | Location |
|---|---|---|
| Detector – A | 10m | Turbine |
| Detector – B | 1.5m | Turbine |
| Detector – C | 1.5m | Hedge |
| Detector – D | 10m | Hedge |

The automatic detector survey measured an index of bat activity (i.e. the number of bat passes per night). The criteria for a bat pass are not important here, as long as all four locations use the same method for determining a bat pass and that method is reported.

This example describes a non-parametric approach to undertaking statistical analysis of bat survey data (i.e. the number of bat passes recorded over a set period for individual bat species).

The assumptions made are as follows:

1. The four bat detectors are considered equal in their ability to detect bats.
2. Bat species are equally likely to be detected at a given distance, e.g. loud bats such as the noctule and quiet bats such as the brown long-eared.
3. Identification of bats using sound analysis is correct.
4. The null hypothesis will be rejected when the $P$-value turns out to be less than 0.05 (5%).

The question asked is as follows:
*Is there a difference between the level of bat activity at the hedge and turbine as measured by a bat pass per night index?*

To illustrate the example bat passes allocated as soprano pipistrelle and noctule bat have been used.

Always start with a graph – see Figure A8.2 and Figure A8.3.

**Figure A8.2 Box plot of soprano pipistrelle activity at the hedge and turbine.**

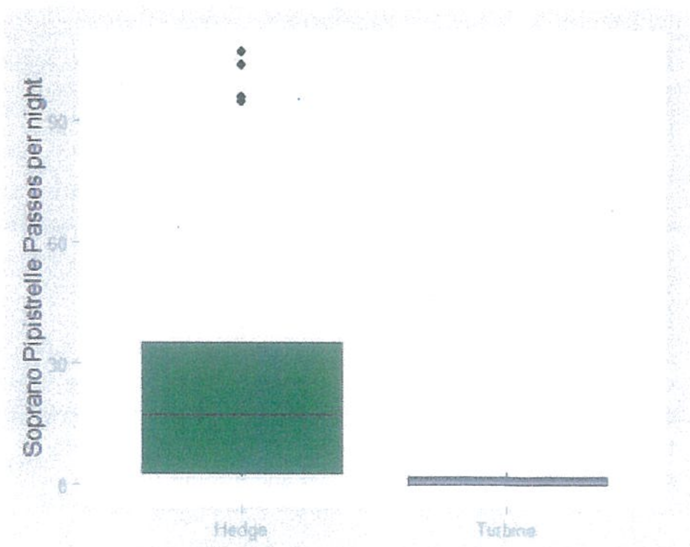
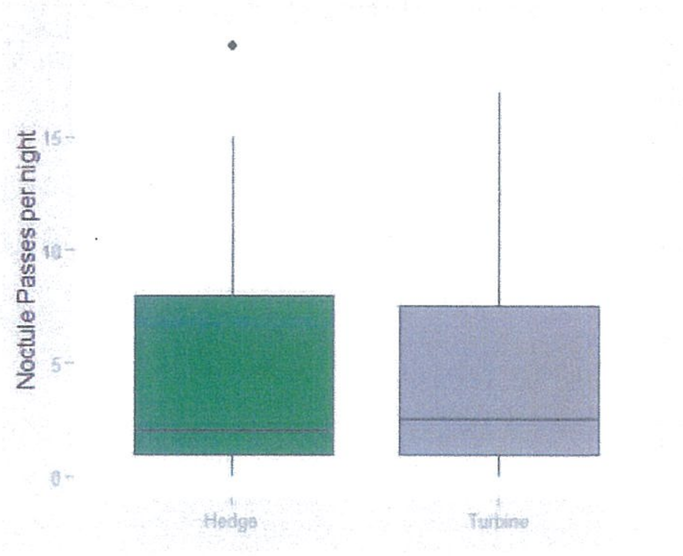


**Figure A8.3 Box plot of noctule bat activity at the hedge and turbine.**




The box plots above clearly show that there is a large difference between the level of soprano pipistrelle activity at the hedge and the turbine but a much smaller difference between the level of noctule bat activity at the hedge and turbine. However, reporting of the results will be much more defensible if testing is carried out to find out whether these differences are statistically significant. The Mann–Whitney U test can be used to test these differences.

- **Null hypothesis:** hedge and turbine soprano pipistrelle (and noctule bat) activity (as measured by passes per night) come from distributions with the same median, i.e. they are not significantly different.
- **Alternative hypothesis:** hedge and turbine soprano pipistrelle (and noctule bat) activity come from distributions with a different median, i.e. they are significantly different.

When this example is put through the Mann–Whitney U test the following results are obtained.

For soprano pipistrelle, the resulting *P*-value ($< 0.05$) tells the ecologist to **reject** the null hypothesis, i.e. hedge and turbine soprano pipistrelle activity is significantly different.

For noctule bat, the resulting *P*-value ($> 0.05$) tells the ecologist they **cannot reject** the null hypothesis, i.e. hedge and turbine noctule bat activity are not significantly different.

The ecologist, using the statistically supported evidence of similar noctule activity at the turbine and hedge, could suggest that an alternative location for the turbine is investigated. Using multivariate statistical techniques (Zuur *et al.*, 2007; Legendre and Legendre, 2012) it would be possible to investigate the assemblage of all bat species observed at the four detector locations. For example, an ANOSIM test (Clarke, 1993) shows that there is a significant difference ($P < 0.001$) between the assemblage of bats at the hedge (1.5m) and the other three locations (hedge 10m, turbine 1.5m and turbine 10m).

## Worked Example 2: Comparing levels of bat activity on a transect

It is possible to carry out simple quantitative analysis of bat activity data to compare the distribution of bats; for example, in different broad habitat types or in different areas within a site. This can be done using a simple chi-square test to investigate whether or not bat activity is distributed as expected from the relative sizes of the habitats or areas (Fowler *et al.*, 1998; Dytham, 2011).

The method involves assigning recorded bat activity into the different sections on the transect to be investigated, measuring the relative lengths of those sections and comparing the bat activity actually observed within each section to the activity expected if bats were randomly distributed across all of the habitats surveyed.

For example, once a transect has been planned on a site, a walkover and/or aerial photographs (e.g. from Google Earth[53]) can be used to section the transect into broad habitat categories such as:

- woodland;
- woodland edge;
- hedgerows;
- pasture.

The length of each section in each habitat is measured. The bat activity within each section can then be quantified. The expected values for bat activity are calculated based on the relative length of each habitat covered by the transect, and compared to the observed values using a chi-square test (Fowler and Cohen, 1990). In this example, illustrated in Table A8.2, the number of bat passes in each of four habitat types is shown along with the length of each habitat within a 6km transect.

**Table A8.2 An example of transect survey data transformed to enable statistical analysis using a chi-square test.**

| Data for common pipistrelle | Woodland | Woodland edge | Hedgerow | Pasture |
|---|---|---|---|---|
| Transect length in habitat (km) | 1 | 2 | 1.5 | 1.5 |
| Observed no. of bat passes | 4 | 21 | 15 | 2 |
| Expected no. of bat passes | 7 | 14 | 10.5 | 10.5 |

The chi-square statistic is calculated as follows:

$$\chi^2 = \Sigma \frac{(\text{Observed - Expected})^2}{\text{Expected}}$$

In this example $\chi^2 = 13.59$. A chi-square distribution table shows that bat activity is not randomly distributed between the habitat types as the result is significant ($P < 0.01$, df = 3). Further analysis can be completed to discover which habitats differ in terms of bat activity, or qualitative interpretation can be made from the relative levels of observed and expected activity. Table A8.2 shows that common pipistrelle activity is higher than expected in woodland edge and hedgerow habitats, and lower than expected in woodland and pasture habitats.

[53] http://www.google.co.uk/intl/en_uk/earth/index.html

Assumptions are made when completing a chi-square test which must be met before any analysis is carried out. In particular, it is assumed that the expected values for the majority of categories are > 5, and therefore the test is not suitable for species or species groups where low levels of activity are recorded.

The G-test is an alternative to the chi-square test. The two methods are interchangeable; if a chi-square test is appropriate then so too is a G-test and the assumptions in each are the same. The outcome of the G-test is a test statistic (G) which is compared with the distribution of chi-square in the same tables as the chi-square test. So why use the G-test? It is easier to calculate by hand but importantly it has been shown to be superior on theoretical grounds to the chi-square test; so the G-test should be preferred (Fowler *et al.*, 1998; Dytham, 2011).

The G-test is calculated as follows:

$$G = 2 \text{ x } \sum \text{aObserved x ln} \left( \frac{\text{Observed}}{\text{Expected}} \right)$$

where:

$\sum$ a = the sum

ln = natural logarithm

When G has been calculated as described above, the Williams' correction must also be applied. The correction factor is calculated as follows:

$$\text{Correctionfactor} = 1 + \frac{(a^2 - 1)}{6nv}$$

where:

a = the number of categories

n = the total sample size

v = the number of degrees of freedom

The adjusted G (or Gadj) is calculated as follows:

$$\text{Gadj} = \frac{G}{\text{Correctionfactor}}$$

In the example above, Gadj is 13.7544366. A chi-square distribution table shows that bat activity is not randomly distributed between the habitat types as the result is significant ($P < 0.01$, df = 3).

The analysis above shows that common pipistrelle activity is higher than expected in woodland edge and hedgerow habitats, and lower than expected in woodland and pasture habitats. Further analysis can be completed to discover which habitats differ in terms of bat activity, or qualitative interpretation can be made from the relative levels of observed and expected activity.

## Worked Example 3: Nathusius' pipistrelle monthly activity

Data has been collected observing Nathusius' pipistrelle bat passes per night for each month from April to October; moon illumination was also recorded for four ranges: 0–25%, 26–50%, 51–75% and 76–100%. Table A8.3 shows the median bat passes per night for each month and moon illumination.

**Table A8.3 Median bat passes per night by month and moon illumination.**

| Month | Moon 0–25% | Moon 26–50% | Moon 51–75% | Moon 76–100% |
|---|---|---|---|---|
| April | 3.00 | NA | 2.00 | 2.75 |
| May | 3.30 | 5.0 | 5.70 | 4.50 |
| June | 4.00 | 6.0 | 12.50 | 5.50 |
| July | 1.00 | 4.0 | 4.00 | 3.00 |
| August | 3.00 | 1.5 | 2.25 | 2.00 |
| September | 16.00 | 2.0 | 18.00 | 11.00 |
| October | 38.75 | 0.5 | 14.50 | 5.00 |

NA = no data available

The question is:
*Is there a difference between the level of Nathusius' pipistrelle bat activity for each month as measured by a bat pass per hour index?*

To treat the months equally, the data needs to go through transformation, from bat passes per night to bat passes per hour (due to the difference in night length between the months; see Figure A8.4) by dividing monthly night bat activity by the average monthly night length (hours). This produces activity per hour for all observations, allowing the months to be compared with each other. The transformed data is presented in a box plot in Figure A8.5.

**Figure A8.4 Average night-time lengths for different months in study.**

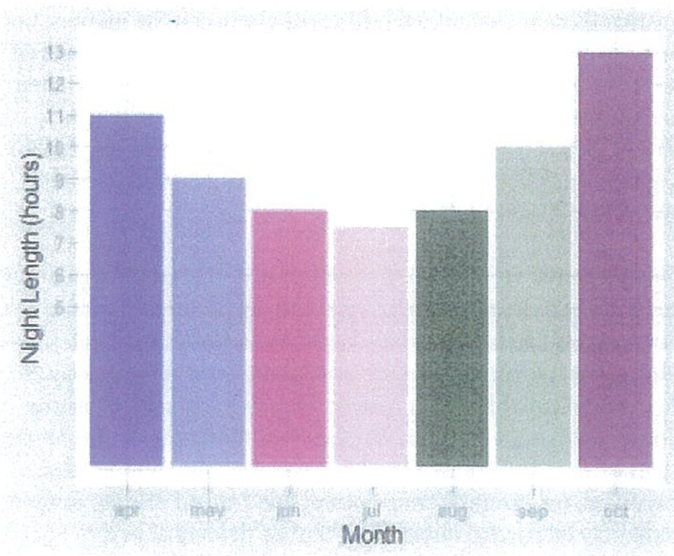
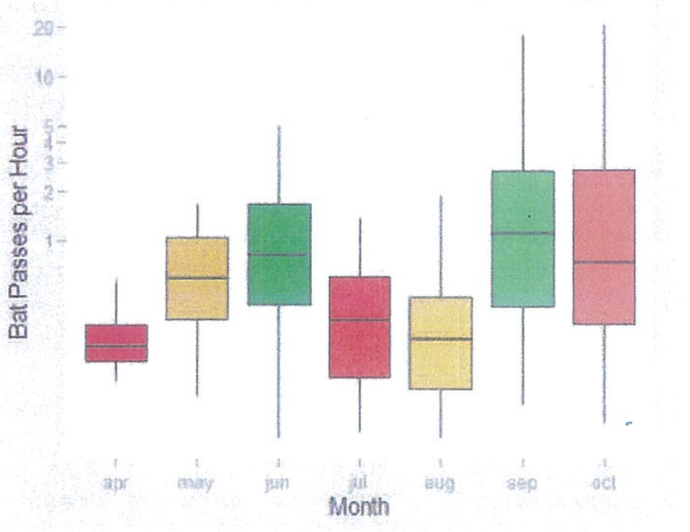


**Figure A8.5 Box plot showing Nathusius' pipistrelle activity by month (passes per hour).**




The box plots above appear to show differences in bat activity in the different months. However, reporting of the results will be much more defensible if testing is carried out to find out whether these differences are statistically significant, i.e. clearly show there is a difference. The Kruskal–Wallis rank sum test, which is a simple non-parametric test to compare the medians of three or more samples, can be used to test for differences.

- **Null hypothesis:** the Nathusius' pipistrelle passes come from distributions with the same median, i.e. they are not significantly different between months.
- **Alternative hypothesis:** the Nathusius' pipistrelle passes come from distributions with a different median, i.e. they are significantly different between months.

When this example is put through the Kruskal–Wallis rank sum test the following result is obtained.

The resulting *P*-value of 0.0018 (i.e. $< 0.05$) tells the ecological consultant to reject the null hypothesis, i.e. Nathusius' pipistrelle passes are significantly different between months. This test tells us that there is a significant difference between the months, but not which month or months. Further testing would be required to investigate which pairs of months are significantly different using further Kruskal–Wallis rank sum testing (Field *et al.*, 2012). When carried out, the further test shows that there is a significant difference in activity ($P < 0.05$) only between the months of August and September.

The objective was to look for evidence of Nathusius' pipistrelle peaks in activity during a given month or group of months. September is believed to be a key time for migration and Nathusius' pipistrelle activity was found to be significantly higher in September than August. However, statistical testing showed that activity of this species was not higher in September than in any of the other months. There may be other factors involved, for example temperature, wind speed or rain, or more data may be needed either from further fieldwork or by combining data from other similar studies; of course it may mean there really isn't a difference. It could also be possible that the sample size is too small, leading to a Type II error.

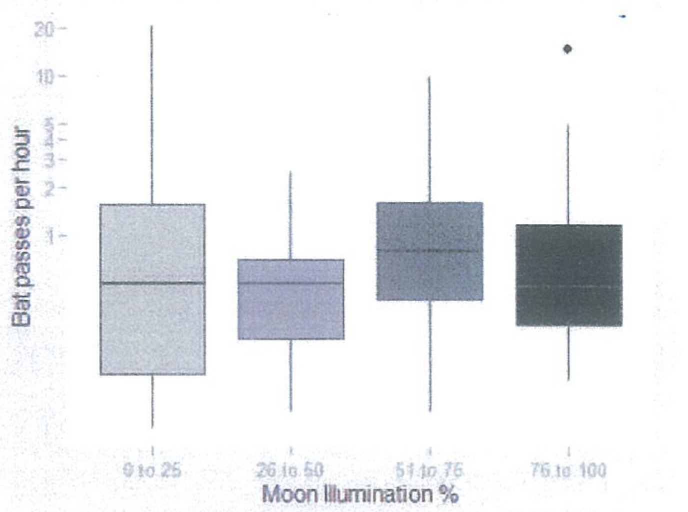
## Worked Example 4: Nathusius' pipistrelle activity and moon illumination

Using the data from Worked Example 3 we investigate the levels of activity of Nathusius' pipistrelle with different moon illuminations.

The question:
*Is there a difference between the level of Nathusius' pipistrelle bat activity for each category of moon illumination as measured by a bat pass per hour index?*

A box plot of the data is given in Figure A8.6.

**Figure A8.6 Box plot showing Nathusius' pipistrelle activity by moon illumination.**




The box plot above appears to show differences in bat activity according to different moon illuminations. However, reporting of the results will be more defensible if we test whether these differences are statistically significant – is there a clear difference? The Kruskal–Wallis rank sum test can be used to test the differences.

- **Null hypothesis:** the Nathusius' pipistrelle passes come from distributions with the same median, i.e. they are not significantly different between moon illuminations.
- **Alternative hypothesis:** the Nathusius' pipistrelle passes come from distributions with a different median, i.e. they are significantly different between moon illuminations.

When this example is put through the Kruskal–Wallis rank sum test the following result is obtained.

The resulting *P*-value of 0.339 (i.e. $> 0.05$) tells the ecological consultant to not reject the null hypothesis, i.e. Nathusius' pipistrelle passes are not significantly different between moon illuminations.

Note: If the box plot showed a trend in activity with increasing moon illumination, we may want to make a hypothesis to explain this trend and then test it. The Jonckheere–Terpstra statistic can be used to test for an ordered pattern (increasing or decreasing) in the medians of the four illumination levels. It is similar to the Kruskal–Wallis test, but incorporates information about whether the order of the groups is meaningful (Field *et al.*, 2012). This test may be particularly useful for, for example, post-construction monitoring purposes – detecting a year on year increase/decrease/no change of activity.

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*Note: where there are several page numbers the main page number(s) are shown in **bold** type; an 'n' suffix to a page number refers to a footnote or a note to a table.*

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