Cyfoeth Naturiol Cymru
Natural Resources Wales

Improving the assessment of habitat area and quality for bats in Wales under Article 17 of the Habitats Directive

The Bat Conservation Trust

NRW Evidence Report No. 37

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Executive Summary Executive Summary
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- Securing our data and information;
- Having a well resourced proactive programme of evidence work;

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- Communicating our evidence in an open and transparent way.

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Er mwyn adrodd ar Erthygl 17 y Gyfarwyddeb Cynefinoedd, rhaid cael gwybodaeth am ddosbarthiad, gwasgariad, poblogaeth a chynefin (maint ac ansawdd) pob un o'r rhywogaethau a restrir yn yr Atodiadau, a hefyd am dueddiadau (gan gynnwys cyfeiriad a maint yn y tymor byr a'r tymor hir). Tynnodd rownd adrodd Erthygl 17 2012 sylw at ddiffyg data dibynadwy ar gyfer y rhan fwyaf o rywogaethau ystlumod y DU. Nid yw wedi bod yn bosibl adrodd ar dueddiadau'n ymwneud â gwasgariad a chynefin ar gyfer unrhyw rywogaeth, a dim ond o safbwynt poblogaeth ar gyfer ambell rywogaeth. Mae data'n ymwneud â thueddiadau ar gael ar gyfer rhai rhywogaethau ar lefel y DU trwy gyfrwng cynlluniau cadw gwyliadwriaeth presennol, ond nid ar lefel Cymru ar gyfer y rhan fwyaf o'r rhywogaethau.

Ar gyfer ambell rywogaeth, ystyrir bod y data'n ddibynadwy, ac mae'n deillio o astudiaethau monitro a/neu awtecolegol hirdymor. O safbwynt rhywogaethau prin eraill, nad oes cymaint o astudiaethau wedi'u cynnal arnynt, ceir diffyg gwybodaeth am yr holl elfennau uchod ar gyfer Cymru. Ar gyfer y rhywogaethau mwy cyffredin sydd i'w cael dros ardal eang, ceir mwy o wybodaeth am eu dosbarthiad a'u gwasgariad. Fodd bynnag, seilir amcangyfrifon y boblogaeth ar allosodiadau hen ddata, ac nid ydynt yn ddibynadwy. Hyd yn hyn, ni fu modd adrodd ar ansawdd y cynefin.

Aeth y prosiect hwn ati i ystyried y data sydd ar gael ar hyn o bryd, gan gynnal ymarfer cwmpasu i ganfod ffynonellau gwybodaeth a dulliau o gynnal asesiadau dibynadwy er mwyn bodloni'r gofynion adrodd, a hefyd er mwyn dod o hyd i unrhyw gyfyngiadau.

2 Executive Summary

Reporting on Article 17 of the Habitats Directive requires information on the distribution, range, population and habitat (extent and quality) for each of the species listed in the Annexes and on trends (including the direction and magnitude in the long and short term). The 2012 Article 17 reporting round highlighted the lack of reliable data for most UK bat species. It has not been possible to report on trends for range and habitat for any species and only for population for some species. Trend data are available for some species at the UK level through existing surveillance schemes, but not at a Wales level for most species.

For some species the data are considered to be reliable and results from long-term monitoring and/or autecological studies. The other rare, but less well-studied species lack information in relation to all the above elements for Wales. For the more widespread and common species, there is more and information on distribution and range. However, the population estimates are based on extrapolations from old data and are not reliable. To date it has not been possible to report on habitat quality.

This project considered the data currently available and undertook a scoping exercise to identify sources of information and approaches / methods for providing sufficiently robust assessments to satisfy reporting requirements and also to identify any constraints.

3 Introduction

Article 17 of the EC Habitats Directive requires Member States to report on the conservation status of all species and habitats of community interest. This includes all resident bat species. Conservation status is assessed using four parameters: range, population, habitat for the species and future prospects.

Natural Resources Wales (NRW) have identified three areas where further information is needed to improve the assessment of the conservation status of Welsh bat species. These areas are:

- population size and population trends;
- distribution and range; and
- habitat for the species, which includes information on area of suitable habitat; area of occupied habitat; habitat quality; and trends in these measures.

This report considers the latter area - habitat for the species.

The Bat Conservation Trust (BCT) was commissioned by NRW to undertake a scoping exercise with the following two aims.

1. Identify existing information and methods that could be used to provide a more robust assessment of habitat area, quality and trends for Welsh bat species, as required by Article 17 of the Habitats Directive.

2. Investigate new sources of data and methods that could be developed to improve future Article 17 assessments.

To address these aims we carried out the following tasks:

- Reviewed the assessment methods used by Member States in previous reporting rounds.

- Compared two methods commonly used to estimate the area of suitable habitat for a species: (a) MaxEnt modelling and (b) classifying habitat maps using species habitat preferences reported in the literature.

- Identified indicators of habitat quality for each bat species included in the Welsh 2007-2012 Article 17 report.

- Provided recommendations for methods and sources of data that could be used to improve the assessment of habitat area, quality and trends in future Article 17 reports.

- Identified areas of further research required to address evidence gaps.

4 Habitat Area

4.1 Article 17 reporting requirements

Section 2.5.1 of the 2007-2012 Article 17 report format (Evans and Arvela, 2011) requires Member States to provide an estimate of the area of habitat occupied by the species in km^2. Habitat is defined in the Directive as "an environment defined by specific abiotic or biotic factors, in which the species lives at any stage of its biological cycle" (Art. 1f).

Optionally, an estimate of the area of suitable habitat may be provided in Section 2.5.9. Suitable habitat is defined as the total area of habitat thought to be suitable for the species, including both occupied and unoccupied habitat.

4.2 Current assessment methods

We reviewed methods used by Member States to assess the area of habitat occupied by species of community interest in previous reporting rounds (2001-2006 and 2007-2012). Where individual species assessments have been made publicly available, only those methods used to assess the area of habitat for bats were considered. Where only summary documents covering all species were available, all assessment methods were considered. A breakdown of methods used by a selection of member states is provided in Appendix I.

Four different methods were used by Member States to estimate the area of occupied habitat, as follows.

a) *The area encompassed by the distribution or range of the species was taken to be equivalent to the area of habitat occupied by the species.*
This method was used for generalist species that utilise a broad variety of habitat types. For the assessments undertaken in Wales, England and Scotland, the area covered by occupied 10km grid squares was taken to be equivalent to the area of occupied habitat. In Ireland, habitat suitability modelling was used to estimate the area of occupied habitat for most bat species (see point 4), with the exception of Natterer's bat and whiskered bat. For these two species the area of habitat estimated by modelling was substantially larger than the species' known range, so for these species their range was taken to be equivalent to the area of occupied habitat.

b) *The habitat requirements of the species were identified and the known area of these habitats was summed.*
This method was used for species with more specialist habitat requirements. In the Scottish assessment the area of habitat occupied by brown long-eared bat was taken to be equivalent to the area covered by woodland in Scotland. This method was also used for lesser horseshoe bat in Ireland, where a variety of habitat classes derived from the CORINE land cover map and the Forest Inventory and Planning System were summed. This area was then overlain onto the range of lesser horseshoe bat to produce an estimate of the area of occupied habitat.

c) *A habitat suitability model was used to estimate the area of suitable habitat, and taken to be equivalent to the area of habitat occupied.*
All assessments that employed habitat suitability models used maximum entropy modelling.

d) The area of occupied habitat was derived from intensive survey of all known populations.
This approach was used for easy-to-survey species with very restricted distribution, and is therefore inappropriate for bats.

4.3 Estimating the area of suitable habitat

The Article 17 report format requires an estimate of the area of habitat occupied by the species. **We recommend that this estimate is arrived at in two stages:**

1. Estimate the area of suitable habitat for the species.

2. Estimate the area of suitable habitat that overlaps with the known distribution of the species, to derive an estimate of the area of occupied habitat.

There are two methods which are commonly used by Member States to estimate the area of suitable habitat for a species.

The first method uses information on bat habitat preferences from previous research to classify habitat maps into suitable and unsuitable areas. We refer to this method as the 'habitat classification method'.

The second method uses species distribution records together with habitat maps and other environmental information to model habitat suitability. A common techniques for modelling habitat suitability is maximum entropy modelling, implemented using the software program MaxEnt (http://www.cs.princeton.edu/~schapire/maxent/).

Habitat suitability maps have already been created for a subset of bat species in Wales using MaxEnt. Details of the methods and data used to create these maps are given in Matthews and Razgour (in press).
Here we compare a habitat suitability map for barbastelle bat created using the habitat classification method (Fig. 1a) to one created using MaxEnt by Matthews and Razgour (in press, Fig. 1b).

To create a habitat suitability map using the habitat classification method, we used data from the Phase 1 Habitat Survey of Wales, the most comprehensive habitat map available for the whole country. This map was derived from extensive field surveys carried out between 1979 and 1997 (Howe et al. 2005). Each Phase 1 habitat type was classified according to its suitability for barbastelle using information provided in the literature as follows:

- Preferred. The habitat is consistently preferred by barbastelle across multiple studies.
- Used. The habitat is noted in the literature as being used by barbastelle, but is not consistently preferred.

- Avoided or unknown. The habitat type is avoided by barbastelle, or no information is available to assess its suitability.

Due to the limited resources available for this exercise a full literature search was not undertaken. Instead information regarding barbastelle habitat preferences was gathered from previously undertaken literature reviews, species guides and other summaries. The full classification of Phase 1 habitat types for barbastelle is provided in Appendix II.

Elevation has a large impact on habitat suitability for bats; suitability modelling suggests that areas above approximately 400m are unsuitable for barbastelles (Zeale, 2011). Therefore the final habitat suitability map was created by mapping areas of preferred and used habitat below 400m (Figure 1a).

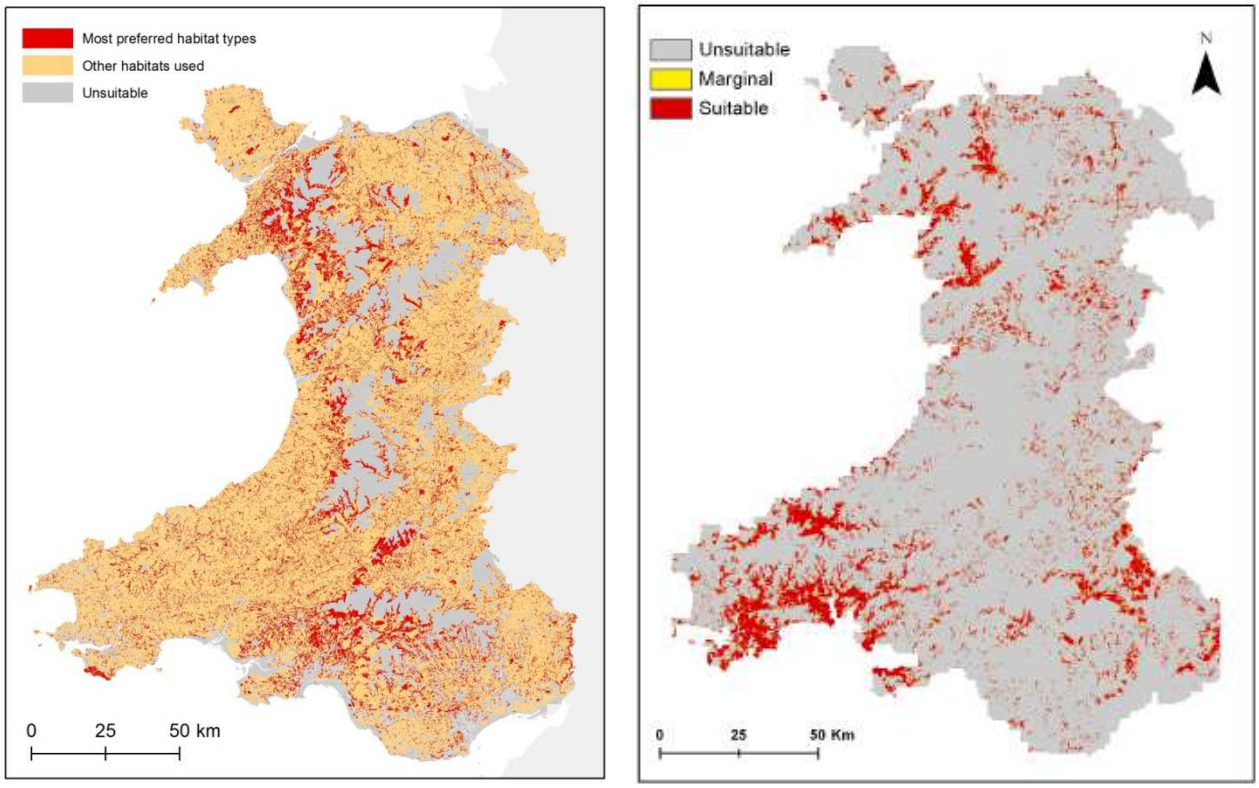

Figure 1. *Habitat suitability for barbastelle in Wales estimated by (a) the habitat classification method; and (b) using MaxEnt. Figure 1b is reproduced from Matthews and Razgour (in press).*

The two techniques produce vastly different estimates of the area of suitable habitat for barbastelle in Wales. They also identify different areas as providing greater concentrations of suitable habitat. The advantages and disadvantages of the two techniques are described in Box 1.

Of the two maps presented in Figure 1, we consider the map produced using MaxEnt to be a more accurate reflection of the distribution of suitable habitat for barbastelle. The map created using the habitat classification method overestimates the area of suitable habitat available. This is primarily because it has been created using only two variables, habitat type and elevation. It does not take into account other variables known to affect bat distribution such as topography and climate, nor does it

consider how these variables may interact with each other to determine habitat suitability. These factors are accounted for when using MaxEnt.
MaxEnt provides a more accurate estimate of habitat suitability and has fewer disadvantages when compared to the habitat classification method. MaxEnt has been shown to be a reliable presence-only technique for modelling habitat suitability for bats (Razgour et al., 2011) and has been used by other Member States in Article 17 assessments.

We recommend that maximum entropy modelling (i.e. MaxEnt) is used to create habitat suitability maps for all Welsh bat species. To ensure these models are interpreted correctly it is important to report on the quality of distribution data, data sources and methods used to build the model alongside the model output.

Box 1. *Advantages and disadvantages of two methods commonly used to estimate the area of suitable habitat for a species*.

The habitat classification method

Advantages:

- Requires a lesser degree of technical expertise than habitat suitability modelling.
- Habitats are classified based on the findings of peer-reviewed research (amongst other sources). Such research should have been designed to limit biases such as non-random sampling, pseudoreplication and spatial autocorrelation, and therefore can be considered reliable.

Disadvantages:

- Information on the full range of biotic and abiotic factors that influence the distribution of a species is time consuming to collate and is often not available. The assessment of habitat suitability using this method is limited to factors that have been investigated previously and can be readily classified into suitable and unsuitable.
- Habitat definitions used in previous research are unlikely to correspond exactly to the available habitat maps. A degree of expert judgement is required when assigning habitat preferences reported in the literature to other habitat classification systems (such as Phase 1).
- Often only classification at the level of broad habitat types is possible. The information needed to comprehensively assess the relationship between species distribution and detailed habitat classifications such as Phase 1 is rarely available.
- If all habitat types used by a species are classified as suitable this can result in an overestimation of suitable habitat, however if only habitat types that are consistently preferred are classified as suitable this can result in an underestimation of suitable habitat.
- This technique almost always relies on the results of research that has taken place outside the area of interest. However species may not demonstrate the same habitat preferences across all landscape types, so extrapolation to different landscapes may be inappropriate.

continued overleaf

MaxEnt suitability modelling

Advantages:

- MaxEnt models are multivariate; they can consider multiple biotic and abiotic variables simultaneously and can model multiple relationship forms including interactions between variables.
- Prior knowledge of the relationship between an environmental variable and bat distribution is not required. The process of building and testing the model can be used to assess the relationship between bat distribution and environmental variables that have not been studied before. If these variables are influential they can be retained in the final model.
- Habitat suitability models can be built using data from the area of interest where sufficient distribution records are available, so extrapolation from other areas is not required.

Disadvantages:

- The data that can be included in the model are limited to environmental predictors that can be mapped or interpolated across the entire area of interest.
- MaxEnt models are built using presence records, which are typically collected in a non-random fashion. The resulting model can therefore be affected by sampling biases, although this can be reduced by sub-sampling the data used to build the model or by using various bias correction techniques during modelling.
- The predictive accuracy of habitat suitability models for species that demonstrate low levels of habitat discrimination (i.e. habitat generalists) is low, although this will also be an issue when using other suitability mapping methods.

Habitat suitability models have already been constructed for barbastelle, Bechstein's bat, serotine, Leisler's bat and lesser horseshoe bat in Wales (Matthews and Razgour, in press; Matthews and Wienhold, in press). Habitat suitability for Bechstein's bat across the UK has also been modelled by Lia Gilmor at Bristol University (Gilmor, in press). This map is based on a 1km grid and uses many of the same data sources as Matthews and Razgour (in press) but includes additional presence data (Figure 2).

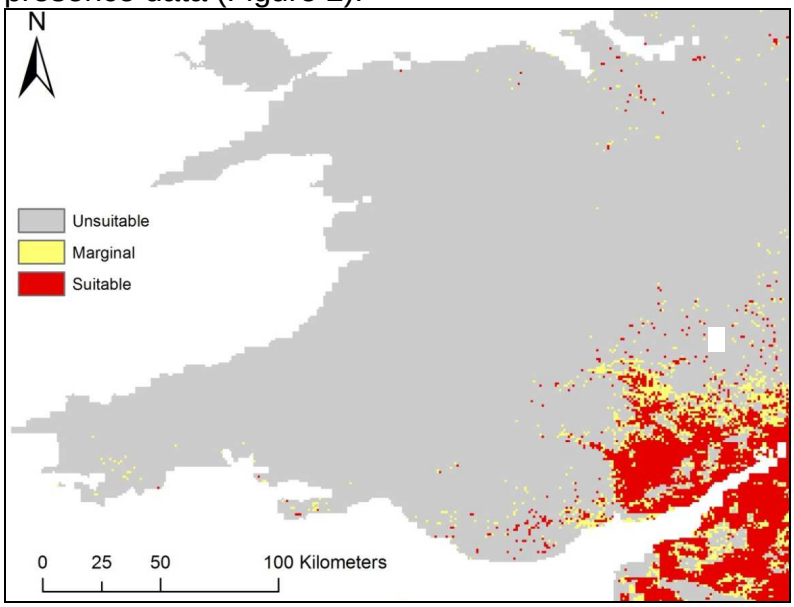

Figure 2. A habitat suitability map for Bechstein's bat in Wales, reproduced from Gilmor (in press).

Researchers at Leeds University, led by John Altringham, have developed a suite of survey methods and mapping tools to aid habitat suitability modelling for bats. This team are also conducting a DEFRA-funded investigation into the effect of roads and rail lines on bats, which has generated a large amount of bat distribution data. These data could be used to improve habitat suitability models in Wales and will be released at the end of the project with permission from DEFRA. There are several additional sources of distribution data and environmental data that could be used to improve existing species distribution models for bats. These data are discussed in Section 2.5 *Improving knowledge of species distribution*, Section 4.3 *Assessing trends in habitat area and quality*, and Section 5 *Suggestions for further research*.

4.4 Estimating the area of occupied habitat

We recommend that the area of habitat occupied by the species should be estimated by intersecting (overlapping) the area of suitable habitat with the known distribution of the species. There are several common approaches to mapping the range or distribution of a species, outlined below. These methods vary in the degree to which they include areas currently without known records of the species.

- *Distribution records are buffered by the typical maximum foraging radius of the species.*
  This method is the least likely to include areas where the species is not actually present. However it is very sensitive the availability and reliability of distribution data. It is a useful technique for species where knowledge of their distribution is reasonably complete, however it will underestimate the distribution of rare or hard to survey species. This method is best suited to buffering roost records, although for most bat species both roost and field records can be used as a record of an individual bat usually indicates a roost is nearby. However this would not be appropriate for species such as Nathusius' pipistrelle that are known to migrant large distances from their roosts, or for species that are hard to identify in the field such as Leisler's bat, where unreliable field records could lead to an inaccurately mapped distribution.
- *The distribution is represented using the number of occupied 10km grid squares.*
  This approach is commonly used in Article 17 assessments. It is a convenient method to implement and avoids giving the impression of a high degree of precision. However the size of the grid squares has little direct ecological relevance, and distributions mapped in this way will encompass areas not actually occupied.
- *Records are merged together to form clusters using gap-filling techniques*. These techniques typically use information on dispersal movements to set the threshold of gaps to be filled. However for bats there is little information regarding typical dispersal movements (as opposed to foraging movements) on which to base these thresholds. Other methods of delimiting clusters, such as density or distribution-based cluster analysis, are best suited to species with tightly clustered occurrences as they will disregard sparse or outlying distribution records. As such they are not appropriate for delimiting species distribution for the purposes of estimating area of occupied habitat.
- *The range of a species is represented using a minimum convex polygon encompassing all distribution records.*
  This technique is the least sensitive to the availability of distribution records but will include large areas from which the species is not known to be present.

For the purposes of estimating the area of habitat occupied by Welsh bat species **we would recommend mapping their distribution either by buffering distribution records by the typical maximum foraging radius of the species or by mapping the 10km grid squares occupied by the species**. The choice of method will be determined by the balance of advantages and disadvantages outlined above. The Bat Conservation Trust can provide information on typical foraging radii for each species.

4.5 Improving knowledge of species distribution

There are several bat species with poorly known distributions in Wales. In order to obtain a robust estimate of the area of habitat occupied by these species improved distribution data are required. Improved distribution data could be generated using targeted field surveys (see below) or through better use of existing data sources such as surveys that are undertaken as part of planning applications or protected species licence returns. Adequate species distribution data is fundamental to the assessment of conservation status and this is one of three areas identified by NRW where improved information is required (Section 1). **We recommend an exercise is undertaken to identify methods and data sources that could be used to improve knowledge of bat species distribution and range for future Article 17 assessments.** A comprehensive assessment of this topic is beyond the scope of this report, however the general recommendations given below should be considered.

We recommend targeted field surveys are established to improve knowledge of the distribution of the following species:

- Barbastelle
- Nathusius' pipistrelle
- Brandt's bat
- Whiskered bat
- Bechstein's bat
- Serotine
- Leisler's bat
- Grey long-eared bat
- Alcathoe bat

Improved distribution data are also required for many Welsh bat species to improve estimates of population size, range size and to confirm the breeding status of the species in Wales (this particularly applies to the grey long-eared bat and alcathoe bat). The design of targeted field surveys should take the requirements of section 2.3 (species range), 2.4 (population) and 2.5 (habitat for the species) of the Article 17 report into account.

An effective way to locate new bat populations is to target field surveys in areas identified as suitable by habitat suitability modelling. **Therefore we recommend that species distribution models should be built for the species listed above (where this has not already been completed)**. Data generated by targeted field surveys can be used to improve and/or ground truth distribution models where appropriate.

Field surveys should use standardised methods and be guided by the results of species distribution modelling. The distribution of cryptic bat species should be investigated using DNA analysis of droppings. BCT can advise on the design of targeted field surveys. BCT's National Bat Monitoring Programme includes surveys specifically designed to provide distribution data for barbastelle, Nathusius' pipistrelle and Bechstein's bat (the Woodland Survey, Nathusius' Pipistrelle Survey and Bechstein's Bat Project respectively). An exercise to investigate the feasibility of extending the Bechstein's Bat Project into Wales has already been completed (Bat Conservation Trust 2008). It may also be possible to incorporate additional surveys specifically targeted at increasing distribution data for Wales into the National Bat Monitoring Programme.

BCT can also advise on the use of the use of DNA analysis to confirm the presence of cryptic species. In 2012 BCT undertook a study to improve knowledge of the distribution of grey long-eared bat using DNA analysis of droppings collected from long-eared bat roosts in target areas. A predictive model was used to identify areas of the UK with suitable habitat for grey long-eared bat. Roosts of long-eared bat species within these study areas were identified by searching the NBMP database and by contacting local bat workers. Droppings were collected by volunteers from within these roosts and submitted to a laboratory for DNA analysis. In 2013 BCT collaborated with the University of Bristol to study the distribution of the cryptic small *Myotis* species whiskered bat, Brandt's bat and alcathoe bat. Bats were trapped under licence in suitable woodlands using mist-nets and harp traps. Droppings were collected from trapped bats for subsequent DNA analysis. Dropping collection kits were also provided to bat workers across the UK to enable them to submit droppings from small *Myotis* bats for this study. For further information on this or any other aspect of field survey design please contact the National Bat Monitoring Programme team at BCT.

There are several projects already underway which incorporate many of the recommendations above. The Rare Woodland Bat Project is a collaboration between NRW, BCT and the Vincent Wildlife Trust, designed to improve knowledge of the distribution of barbastelle and Bechstein's bat in Wales. It will also produce distribution records for a range of other bat species where possible. Habitat suitability modelling has been used to identify target areas. Suitable woodlands will be identified within these target areas and will by surveyed using standardised methods by a network of trained volunteer surveyors.

The North Wales Serotine Project is a volunteer-led project designed to improve knowledge of the distribution of serotine in Wales. The information produced by this project will also be of use in future Article 17 reports.

5 Habitat quality

5.1 Article 17 reporting requirements

Section 2.5.4 of the Article 17 report requires Member States to assess the quality of the species' habitat using the following categories.

- Good. Species survival is not limited by the quality of its habitat.

- Moderate. Population size or reproduction is limited by habitat quality, but not to the extent that it prevents the population from being viable.
- Bad. Habitat quality is a major problem for the survival of the species.
- Unknown. Habitat quality cannot be assessed.

5.2 Current assessment methods

In the 2007-2012 assessments carried out in Wales, England and Scotland, the quality of habitat for all bat species was reported as unknown. In the Irish assessment habitat quality for all bat species was reported as good, based on a lack of evidence of population or range contractions and the fact that the extent of preferred habitat types was either stable or increasing. The assessment of habitat quality in Northern Ireland was identical to the Irish assessment for all bat species apart from whiskered bat, where quality was reported as moderate, although no information was given for how this decision was reached.

5.3 Assessing habitat quality

To assess whether habitat quality may limit species survival the following information is required.

1. Information on the habitat characteristics that determine habitat quality for the species. These characteristics can then be used as indicators of habitat quality.

2. Baseline data describing the current state of these habitat quality indicators.

3. Either:
   a) Information describing the favourable range of these indicators, which can then be compared to baseline data to establish whether habitat quality is good, moderate or bad; or
   b) The current conservation status of the species' range or population. If the conservation status of the species' range **and** population is favourable then it can be inferred that habitat quality is not limiting the survival of the species and that habitat quality is therefore good (as per the definition provided by Evans and Arvela, 2011). If the conservation status of the species' range or population is not favourable then further investigation is needed to identify the cause.

To address the requirement described in (1) above, the habitat preferences of all bat species that are part of the Welsh Article 17 assessment were reviewed to identify characteristics that could be used as indicators of habitat quality for the species. Due to limited resources available for this exercise a full literature search was not undertaken, instead information regarding bat habitat preferences was gathered from previously undertaken literature reviews, species guides and other summaries. Emphasis was placed on indicators of habitat quality that are subject to human management or pressures, that can be measured over regional or national scales and could potentially show a change over the long-term monitoring period specified by the Article 17 reporting format, which is 4 reporting cycles or 24 years. The top eleven indicators, which are important to ten or more species, are shown in Table 1. The full list of indicators for each species is provided in Appendix III.

Table 1. Indicators of habitat quality for bats in Wales. The indicators given here are potential indicators of habitat quality for 10 or more species.

Indicator	Number of species
Abundance of aerial invertebrates	15
Extent of broadleaved woodland	14
Availability of suitable roost sites in built structures	13
Extent of parkland with scattered trees	13
Presence of a structurally diverse woodland edge	13
Extent of riparian vegetation	12
Density of damaged, senescing or dead trees	12
Density of connective landscape features	12
Density of trees with rot or woodpecker holes	11
Density of trees with cracks	10
Number of woodland or in-field ponds, streams or ditches	10

5.3.1 Availability of suitable roosting sites

The availability of suitable roost and hibernation sites is of fundamental importance to bat populations and is therefore a potentially important indicator of habitat quality for bats. Bats predominantly roost in either built structures or trees, depending on the species, and the requirements for each vary. Species that roost in trees use features such as rot holes, woodpecker holes, damaged limbs and flaking bark. These features are more commonly found in mature or veteran trees, so the abundance of such trees can also be an indicator as habitat quality for bats. The National Forest Inventory monitors veteran trees in a sample of woodlands, recording factors such as the presence of rot holes, woodpecker holes, hollowing, bark tears, dead wood in the crown, etc. This survey also monitors the number of dead trees and the degree of damage to trees in sample plots, and so offers the potential to provide a range of indicators of bat habitat quality (see section 4.3.2 for further discussion).

Bats that roost in built structures generally require an accessible and undisturbed roost space. Different species have different requirements for the dimensions and temperature profile of the roost. Bats roosting in buildings will be affected by changing building practices which can make buildings less suitable for bats and are therefore a potential influence on habitat quality. One practice that is of particular concern is the increasing use of breathing roofing membranes. It is known that bats can become tangled in the fibres of breathable roofing membranes and large numbers of bats can be killed in this way. The impact of breathable roofing membranes on bats is being investigated by a study at the University of Reading, with the results due to be released this year. **If the impact on bats is found to be significant it may be necessary to establish a programme to monitor the use of breathable roofing membranes and the effects this has on bat populations.**

The National Bat Monitoring Programme surveys over 1,000 roosts in buildings and hibernation sites annually. This data is used produce robust population trends and

also provides invaluable distribution information (see section 2.5). However data on the condition and level of disturbance each site is only collected systematically in the first year that the site is monitored. It is also inadvisable to use evidence of a decline in colony size at a particular site as evidence of a decline in the suitability of the roost structure, as bats can abandon roost sites for a variety of reasons unrelated to the suitability of the structure such as an increase in colony size or a build-up of parasites. For these reasons NBMP data is not suitable for monitoring habitat quality.

There are several species where a significant proportion of the population is contained with Special Areas of Conservation and/or Sites of Special Scientific Interest. This includes roosts of greater and lesser horseshoe bat. **Common Standards Monitoring of roost condition at these sites could be used as an indicator of roost availability for these species.**

5.3.2 Thresholds of habitat quality

The availability of quantitative information that could be used to describe the favourable range of the indicators given in appendix III was assessed. This information was rarely reported in the literature reviews consulted, so it is not possible to establish thresholds of habitat quality as part of this exercise. If this information is required a more comprehensive review of primary literature would be needed. However, even with a more comprehensive review it is likely to prove difficult to establish thresholds in measures of habitat quality as the relevant information is not often reported.

It is possible to use modelling techniques such as MaxEnt to provide a quantitative measure of habitat suitability. This requires a two-stage modelling process to separate out the influence of indicators of habitat quality from measures of habitat suitability that are not measures of habitat quality *per se*, such as altitude or topography. This also requires detailed maps of habitat quality indicators across Wales, which are not generally available (although see Section 4.3).

In the absence of better data it is recommended that habitat quality for bats in Wales is assessed using a combination of the conservation status of the species' population and/or range and information on trends in indicators of habitat quality (see Section 4). However, it is recognised that for many bat species better information on population and range size is required for this to be possible.

6 Trends in habitat area and quality

6.1 Article 17 reporting requirements

Section 2.5.6 of the Article 17 report requires Member States to assess the direction of the trend in habitat for the species over a recommended period of 12 years. Optionally, the trend over a longer time period, recommended to be 24 years, can be reported in Section 2.5.7 (Evans and Arvela, 2011).

The following categories are used.

- Stable. Both habitat area and habitat quality are stable.

- Increasing. Both area and habitat are increasing, or one is increasing while the other remains stable.
- Decreasing. Both area and quality are decreasing, or one is decreasing while the other remains stable.
- Unknown. Area and quality display opposite trends, or no data is available.

6.2 Current assessment methods

In the Welsh, English, Scottish and Northern Irish assessments for 2007-2012 the trend in habitat for all bat species was reported as unknown. In the Irish assessment the trend was reported as either stable or increasing, based on increases in preferred habitat types and a lack of evidence of population or range contractions.

6.3 Assessing trends in habitat area and quality

In Section 2 of this report we recommend that the area of suitable habitat for a species is estimated using habitat suitability modelling. However habitat suitability modelling is not a suitable technique for monitoring trends in habitat for the species. Technical advances in remote sensing, the increasing availability of bat distribution data and variation between model iterations mean that the results of species distribution modelling are unlikely to be comparable between reporting rounds. **Instead we recommend that habitat trends are assessed using indicators of habitat area and quality**.

Here we describe sources of information that can be used to provide baseline data and trend information for the indicators of habitat area and quality identified in Section 3.3 and Appendix III. This includes datasets that are currently available and datasets that could be developed in the future.

6.3.1 Area and condition of broad habitat types

The Countryside Survey has two components, a field survey which monitors the extent and condition of habitats, vegetation, soils and freshwater in sample 1km squares across the UK and a land cover map derived from satellite imagery (Carey et al., 2008). The field survey component of the Countryside Survey provides information which could be used to monitor trends in habitat area and quality for bats in Wales. Field Surveys have taken place in 1978, 1984, 1990, 2000 and 2007. An analysis of trends is produced by the Centre for Ecology and Hydrology (CEH), including trends from Wales and for the Welsh upland and lowland zones, although changes to the survey methodology mean data from previous surveys are not always directly comparable. An effort is made to survey the same sample squares in each survey round, so the Countryside Survey provides robust trend information. Results from sample squares are extrapolated to country and UK level, which can be used to provide baseline data on habitat area, however the accuracy of such extrapolation may be limited by the selection of sample squares. This does not affect the calculation of trends.

The following Countryside Survey parameters would be particularly useful for developing indicators of habitat area and quality for bats. The survey reports produced by CEH note the extent to which current category definitions are comparable with previous surveys. As habitat suitability for bats declines with increasing elevation, trends in the Welsh lowland zone should be prioritised over those in the upland zone.

- The extent (length) of woody linear features; hedgerow height, width and gappiness.
- Area of semi-natural grassland (neutral, acid and calcareous).
- Area of broadleaved, mixed and yew woodland; number of ancient woodland indicator species in sample plots.
- Area of bog.
- Area of fen, marsh and swamp.
- Area of standing water and canals; area of rivers and streams; number of ponds; ecological condition of ponds; abundance of woody plant species in streamside sample plots.

The second component of the Countryside Survey, the land cover derived from remote sensed imagery, can be unreliable when classifying habitat types such as grasslands so it should be used with caution. Significant differences in the methods used to produce the land cover map between survey rounds make it unsuitable for monitoring habitat trends.

The Habitat Inventory for Wales, a collaboration between Environment Systems, the University of Aberystwyth and NRW, has produced an updated Phase 1 map of Wales using remote sensed imagery. This map offers a substantial improvement over the Countryside Survey land cover map, however it is also affected by a similar set of issues. The utility of this map to provide baseline and trend information for habitats in Wales should be assessed when it is released.

Baseline data and trends in agricultural land classes and livestock are reported by the Agricultural and Horticultural Survey for Wales (Neil, 2013). This is an annual survey with comparable data available from 1998 onwards. The following parameters are particularly relevant for developing indicators of habitat area and quality for bats in Wales.

- Extent of permanent grazing.
- Extent of rough grazing.
- Extent of farm woodland.
- Number of cattle (of relevance to greater horseshoe bat, whose diet includes a high proportion of dung invertebrates).

Recommendation: Develop indicators of habitat area and quality for Welsh Article 17 bat species using trend information reported by the Countryside Survey, the Habitat Inventory for Wales and the Agricultural and Horticultural Survey of Wales.

6.3.2 Quality and extent of woodland

The extent of broadleaved woodland was identified as a potential indicator of habitat quality for 14 of the 15 bat species that are currently part of the Welsh Article 17 report. Woodland characteristics such as the structural diversity of the woodland edge and the availability of damaged, senescing or dead trees were also important for a large number of species.

Baseline and trend information for the quality and extent of woodland in Wales is provided by the National Forest Inventory. This survey is overseen by the Forestry Commission Shared Functions team in Edinburgh. This survey has two components. The first is a map of all woodland in the UK greater than or equal to 0.5ha in size, with canopy cover of 20% or more and a minimum width of 20m. This map has been created using a combination of remote sensed data, aerial photographs and Ordnance Survey Mastermap data. It is updated annually and can be used to provide information regarding woodland patch size, configuration and woodland type.

The second component of the National Forest Inventory is a systematic survey of a sample of woodlands, repeated every five years. This survey records a large number of parameters of direct relevance to bats, including the structure and species composition of the canopy and understorey layers, the structure of the woodland edge, tree density, the density of standing and lying dead wood, management history, presence of invasive species and adjacent land use. These data are used to provide a measure of woodland condition. Baseline and trend information is reported on a regional basis, including for Wales.

Additional information on woodland character can be derived from LiDAR data. These data have already been used to create a map of riparian tree distribution for the Keeping Rivers Cool Project (Figure 3, Section 4.3.3). LiDAR data could also be used to measure canopy structure, canopy closure and the structure of the woodland edge. However LiDAR maps are not updated on a regular basis. They can be used to provide baseline information and are an extremely valuable resource for further research (see Sections 5.1-5.3), but cannot be used to monitor trends.

Recommendation: Develop an indicator of woodland quality for bats in Wales using National Forest Inventory data. BCT is currently investigating the feasibility of using National Forest Inventory data to research and monitor woodland quality for bats, including the development of a UK-wide woodland quality indicator. There is substantial interest in this from the Forestry Commission.

6.3.3 Quality and extent of riparian habitat

The extent and structural diversity of riparian habitat was identified as a potential indicator of habitat quality for 12 of the 15 bat species currently part of the Welsh Article 17 report. Riparian habitat is one of many features monitored by the River Habitat Survey (RHS), co-ordinated by the Environment Agency. This survey involves recording features of the river channel, bank and surrounding land-use at 50m intervals along a 500m section of river. Two ‘baseline’ surveys have been conducted in 1994-6 and 2007-8, for which three randomly selected sites in every 10km grid square in Wales, England and Scotland were sampled. Additional RHS surveys have been carried out on an ad-hoc basis at other sites. Going forward there are no plans to repeat a comprehensive baseline survey, however a rolling monitoring program at Water Framework Directive surveillance sites is envisaged, which will continue to give a good geographic spread of sample locations. The following sections of the RHS survey are of particular relevance to bat habitat quality:

- Section F: Banktop land-use and vegetation structure. This section records land-use within 5m of the river bank and the structure of vegetation on the bank face and top. The land-use categories ‘broadleaved/mixed woodland’,

'broadleaved/mixed plantation' and 'scrub or shrubs' are likely to indicate the most favourable riparian habitats for bats. Structural complexity of bank vegetation is measured using four order categories from 'bare' to 'complex'. Greater complexity indicates greater habitat quality for bats.

- Section J: Extent of trees and associated features. This section records the density of trees along the river using five ordered categories from 'isolated/scattered' to 'continuous'. A greater density of trees indicates greater habitat quality for bats. The presence of overhanging boughs is also linked to greater foraging activity by Daubenton's bats (Langton et al., 2009) and so could be used as an indicator of habitat quality for this species.

Baseline information on the extent and structural diversity of riparian habitat is provided by the map of riparian vegetative objects produced from LiDAR data by the Environment Agency's Keeping Rivers Cool Project (Fig. 3). This data is available free of charge to NRW. However this resource is unlikely to be updated so it cannot be used to provide trend information.

Figure 3. Sample map of vegetative objects produced using LiDAR data by the Environment Agency as part of the Keeping Rivers Cool project.

Recommendation: Investigate the feasibility of using data from the River Habitat Survey and Keeping Rivers Cool project to provide a baseline measure of riparian habitat quality for bats, and to monitor trends in riparian habitat quality for future Article 17 assessments.

6.3.4 Water quality

Many bat species feed on invertebrates with an aquatic larval stage. Water quality has a strong influence on the diversity and abundance of aquatic invertebrates and therefore it has potential to act as an indicator of habitat quality for bats.

Water quality is monitored by NRW at Water Framework Directive surveillance sites. Of the parameters monitored, those with the most direct relevance to bats are the number of macroinvertebrate taxa (a measure of invertebrate species richness) and the average pressure sensitive score per taxon (a measure of the pollution tolerance of the invertebrate community). Invertebrate abundance data is collected by some surveyors but this does not happen systematically.

The use of water quality metrics monitored under the Water Framework Directive offers potential to provided baseline data and trend information for monitoring bat habitat quality. It would also be possible to construct a bat-specific indicator of water quality for Wales by selecting taxa known to form part of a bat's diet and/or weighting the indicator by the mass of the invertebrate taxa. However, the relationship between bat activity, invertebrate diversity and water quality is not fully understood (see Section 5.4). Further research is needed to clarify these relationships before an indicator can be constructed.

6.3.5 Invertebrate abundance

The predominant invertebrate orders in the diets of Welsh bats are Diptera, Lepidoptera and Coleoptera. Lepidoptera (moths) form a significant part of the diet of nine species that are part of the Article 17 assessment (Appendix III), therefore moth abundance could be used as an indicator of habitat quality for bat species that feed predominantly on moths. Rothamsted Research currently monitor the diversity and abundance of moths using a network of light traps throughout the UK. Six light traps are operated in Wales, although historically 57 sites were sampled. Data from the light trap network are used to create the biodiversity indicator 'S9 Terrestrial Insect Abundance: Moths' for Scottish Natural Heritage, and a similar indicator could be constructed for Wales. The species included in this indicator could be tailored to reflect the diet of bat species that feed predominantly on moths. However, moth abundance can vary greatly between years. When evaluating the utility of this indicator, consideration must be given to the magnitude of annual variation and the ability of the indicator to show trends over the timescales required by the Article 17 report.

The light trap network also catches a range of non-moth invertebrates, particularly Chironomidae, which form a significant part of the diet of many bat species. These invertebrates are termed **'**bycatch' and they are stored by Rothamsted Research but not currently analysed. Rothamsted would be happy to donate this bycatch to an external organisation for research and/or the construction of additional invertebrate abundance indicators, however this would be resource intensive. If this were to be carried out at Rothamsted it would require the establishment of a dedicated post.

Recommendation: Establish a pilot project in conjunction with Rothamsted Research to investigate the feasibility and utility of using data from the light trap network to estimate baseline and trend information for moth abundance in Wales.

6.3.6 Deer browsing pressure in woodlands

Browsing by deer alters the species compostion and structural diversity of the woodland understorey (Gill and Fuller, 2007). In the long term deer browsing can also affect woodland regeneration. Deer browsing pressure therefore has the potential to affect habitat quality for bat species that forage within woodland, which includes almost all Welsh bat species.

Deer population numbers are not systematically monitored in Wales. The distribution of deer species is monitored by the Deer Distribution Survey, co-ordinated by the British Deer Society. This survey was undertaken in 1972, 2002, 2007 and 2011. It maps the presence of the six deer species in each 10km grid square across the UK

(see Figure 4 for an example) using distribution records provided by British Deer Society members and the general public. It provides a crude measure of the spread of deer across the UK over this time period.

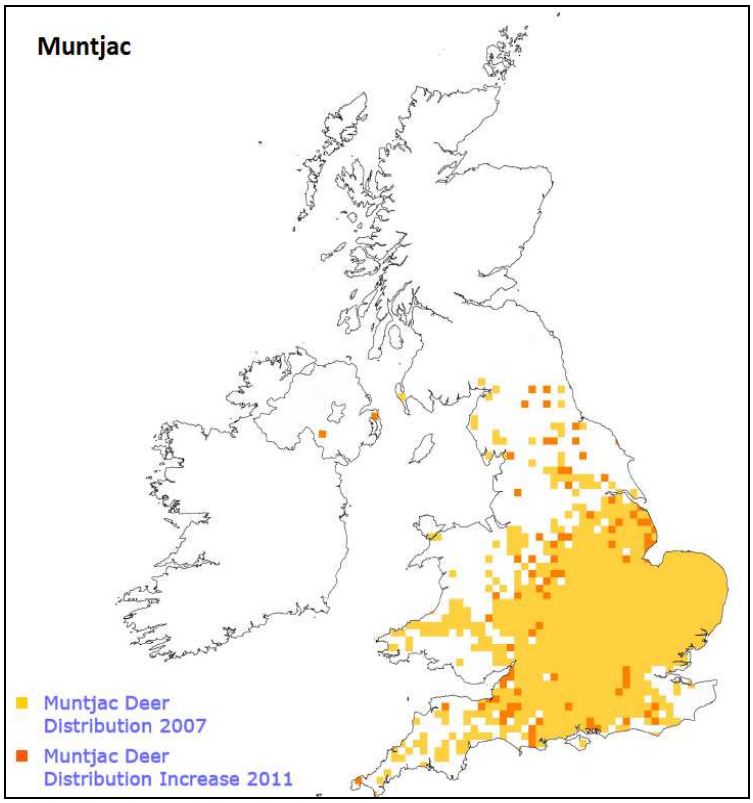

Figure 4. **Distribution of muntjac deer recorded by the Deer Distribution Survey across the UK in 2011.**

There are several sources of data that could be used to develop an indicator of deer browsing pressure on woodlands. The most comprehensive source is the National Forest Inventory (Section 4.3.2). The impacts of deer on trees, saplings and seedlings are assessed by this survey. Deer browsing pressure is currently monitored annualy at sites in the Elwy Valley, and this will be extented to the Wye Valley in 2014. The impact of deer at these sites is measured using the Active Deer Impact System, which scores the frequency of deer signs and browsing damage along a walked transect. The impact of deer is also monitored on the Welsh Government Forest Estate by Natural Resources Wales, focusing mainly on planted and natural regeneration. Monitoring on ancient woodland sites is undertaken by Forest Conservation Managers.

Although the impact of deer on woodland structure is well studied, the effects of woodland structure on bats are known only for a few species. The current priority is for further research to establish the impact of deer browsing on bat habitat quality (Section 5.1).

7 Suggestions for further research

During this scoping exercise we identified several areas where information on bat habitat preferences is lacking. In order to provide comprehensive species-specific guidance, particularly on the factors affecting habitat quality for bats, further research is needed in the following areas:

7.1 Characteristics of woodland

Woodland is an important habitat for Welsh bat species, however the effect of woodland characteristics on bat habitat quality is known for only a few species. It is particularly important to understand the relationship between bat activity and woodland management techniques such as coppicing and thinning, given recent government recommendations to bring more woodlands into active management.

The effect of deer browsing on woodland flora is well studied. Browsing simplifies woodland structure, alters species composition and supresses regeneration, which has the potential to affect habitat quality for bats. Deer browsing has negative impacts on woodland birds (Gill and Fuller, 2007) and small mammals (Flowerdew and Ellwood, 2001; Putman et al., 1989), although the latter group is less well studied and could also benefit from further research. It also affects a wide variety of invertebrates, and has a strong negative effect on moth densities (Fuentes-Montemayor et al., 2011).

Deer browsing may therefore affect bat species that feed predominantly on moths, such as brown long-eared bat and barbastelle. Further research investigating the impact of deer browsing on other invertebrate taxa found in the diet of woodland-specialist bat species is needed. Deer browsing may also negatively impact bats that prefer a dense understorey, such as Bechstein's bat. However increased deer browsing was shown to have a positive effect on the activity of common pipistrelle in Scotland, a bat that prefers more open woodland (Fuentes-Montemayor 2013).

The data from the National Forest Inventory, Deer Initiative and LiDAR survey provide an opportunity to establish the relationship between woodland characteristics, woodland management, deer browsing and habitat quality for bats.

7.2 Characteristics of connective features

All Welsh bat species, with the exception of noctule, make regular use of woody linear features such as hedgerows and treelines for foraging and commuting. Hedgerow trees are important to soprano pipistrelle and brown long-eared bats for foraging (Burrows, 2014; Boughey et al. 2011), while Daubenton's bat, Natterer's bat and Bechstein's bat have all been recorded making use of hedgerow trees as roost sites. Hedgerow height is also important for soprano pipistrelle, greater horseshoe bat and lesser horseshoe bat (Ransome, 1996; Limpens and Kapteyn, 1991). Information on the effects of characteristics such as hedgerow height, hedgerow width and the density of hedgerow trees is needed for a greater range of species to be able to properly monitor the quality of connective features for bats.

7.3 Habitat fragmentation and landscape connectivity

Research suggests that landscape connectivity could be of great importance to UK bats, however evidence of the kind needed to inform conservation action is lacking.

Studies have shown that the size of a habitat patch and the degree to which it is connected to other habitat features can determine the probability that it will be used by foraging bats (Frey-Ehrenbold et al. 2013; Murphy 2012; Fuentes-Montemayor 2013). However it is not clear how factors which affect the selection of individual foraging patches scale up to affect distribution at a larger scale. For example, how is roost location or the national distribution of a species affected by the average distance between habitat patches, average patch size or the density of connective features in the landscape?

Habitat networks in Wales have been mapped using the least-cost analysis programme BEETLE, developed by Forest Research (Latham et al., 2008). This program uses minimum area requirements and typical dispersal distances to identify networks of habitat patches that are functionally connected. Unfortunately these parameters are unknown for most bat species, making the identification of habitat networks for bats difficult.

Various data sources now exist that could be used to provide accurate measures of habitat fragmentation and connectivity at a landscape scale. The map of woody vegetative features produced as part of the Habitat Inventory of Wales offers great potential to investigate the effect of such features on landscape connectivity for bats. LiDAR data could also be used to map connective features. Further research is needed to establish the degree to which bat species are affected by habitat fragmentation and connectivity at a landscape scale. The Bat Conservation Trust is currently investigating ways of addressing these questions and would welcome collaborations with interested organisations.

7.4 Water quality

Many bat species feed on invertebrates with an aquatic larval stage, therefore water quality has the potential to affect habitat quality for bats. However, studies investigating the effect of water quality on bat activity have produced conflicting results. Langton et al. (2009) found increased activity of Daubenton's bats was associated with higher water quality, whereas previous research indicated they show a preference for eutrophic water (Vaughan et al., 1996; Kokurewicz, 1995). Eutrophic water bodies support a higher abundance of pollution tolerant invertebrates, however species diversity is reduced, so prey availability becomes strongly tied to the emergence periods of the reduced number of species present. Water bodies with higher water quality will support lower densities of pollution tolerant invertebrates but have greater species diversity, so prey availability is likely to be more consistent over time. Further research is needed to clarify the relationship between water quality and habitat quality for a wider range of bat species.

7.5 Autecological studies

There are limited autecological studies of Leisler's bat, Nathusius' pipistrelle, serotine, whiskered bat and Brandt's bat. Further research into the habitat preferences of these species would be valuable. An MSc project looking at the distribution and preferences of whiskered, Brandt's and alcathoe bat is currently being completed at Bristol University. The results of this project will be useful for identifying indicators of habitat quality for these species.

8 Summary of recommended options

Below is a summary of the recommendations made in this report.

8.1 Habitat area

1. The Article 17 report format requires an estimate of the area of habitat occupied by the species. We recommend that this estimate is arrived at in two stages:
   a) Estimate the area of suitable habitat for the species.
   b) Estimate the area of suitable habitat that overlaps with the known distribution of the species to derive an estimate of the area of habitat occupied.
2. Maximum entropy modelling (i.e. MaxEnt) should be used to create habitat suitability maps for all Welsh bat species.
3. For the purposes of estimating the area of occupied habitat, bat distribution should be mapped either by buffering distribution records by the typical maximum foraging radius of the species or by mapping the 10km grid squares occupied by the species.
4. We recommend an exercise is undertaken to identify methods and data sources that could be used to improve knowledge of bat species distribution and range for future Article 17 assessments.
5. Targeted field surveys should be established to improve knowledge of the distribution of the following species:
   a) Barbastelle
   b) Nathusius' pipistrelle
   c) Brandt's bat
   d) Whiskered bat
   e) Bechstein's bat
   f) Serotine
   g) Leisler's bat
   h) Grey long-eared bat
   i) Alcathoe bat

   Field surveys should use standardised methods and be guided by the results of species distribution modelling. The distribution of cryptic bat species should be investigated using DNA analysis of droppings.

8.2 Habitat quality

6. If the impact of breathable roofing membranes on bats is found to be significant it may be necessary to establish a programme to monitor their use and the effects this has on bat populations.
7. Common Standards Monitoring data could be used to provide an indicator of roost availability for species where a significant proportion of roosts are contained within SAC/SSSIs.
8. In the absence of better data it is recommended that habitat quality for bats in Wales is assessed using a combination of the conservation status of the species' population and/or range, and information on habitat trends.

8.3 Trends in habitat area and quality

9. Habitat trends should be assessed using indicators of habitat area and quality.
10. Develop indicators of habitat area and quality for Welsh Article 17 bat species using trend information reported by the Countryside Survey, the Habitat Inventory for Wales and the Agricultural and Horticultural Survey of Wales.

11. Develop an indicator of woodland quality for bats in Wales using National Forest Inventory data. BCT is currently investigating the feasibility of using National Forest Inventory data to research and monitor woodland quality for bats, including the development of a UK-wide woodland quality indicator. There is substantial interest in this from the Forestry Commission.
12. Investigate the feasibility of using data from the River Habitat Survey and Keeping Rivers Cool project to provide a baseline measure of riparian habitat quality for bats, and to monitor trends in riparian habitat quality for future Article 17 assessments.
13. Establish a pilot project in conjunction with Rothamsted Research to investigate the feasibility and utility of using data from the light trap network to estimate baseline and trend information for moth abundance in Wales. The pilot project should:
    a) Calculate historical trends in moth abundance in Wales
    b) Establish a baseline measure of moth abundance
    c) Identify the data that would need to be supplied by Rothamsted Research to calculate trends to going forward.
    d) Evaluate the need for additional light trap monitoring sites
    e) Evaluate the utility of the indicator for use in the Article 17 reporting process.

8.4 Suggestions for further research

14. Research investigating the effects of the following factors on bat habitat quality is required to address evidence gaps:
    a) Characteristics of woodland
    b) Characteristics of connective features
    c) Habitat fragmentation and landscape connectivity
    d) Water quality
    e) Autecological studies of Leisler's bat, Nathusius' pipistrelle, serotine, whiskered bat and Brandt's bat.

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10 References

10.1 Literature referenced in the report

Bat Conservation Trust, 2008. The Feasibility of Extending the Bat Conservation Trust's Bechstein's Bat Survey Project to Wales. Bat Conservation Trust and Countryside Council for Wales.

Boughey, K.L., Lake, I.R., Haysom, K.A., Dolman, P.M, 2011. Improving the biodiversity benefits of hedgerows: How physical characteristics and the proximity of foraging habitat affect the use of linear features by bats. Biological Conservation 144: 1790-1798.

Burrows, L., 2014. Bat species factsheets. Somerset County Council.

Carey, P.D., Wallis, S.M., Emmett, B.E., Maskell, L.C., Murphy, J., Norton, L.R., Simpson, I.C., Smart, S.S., 2008. Countryside Survey, Centre for Ecology & Hydrology.

Evans, D., Arvela, M., 2011. Assessment and reporting under Article 17 of the Habitats Directive. Explanatory notes and guidelines for the period 2007-2012. European Topic Centre on Biological Diversity.

Flowerdew, J.R., Ellwood, S.A., 2001. Impacts of woodland deer on small mammal ecology. Forestry 74: 277-287.

Frey-Ehrenbold, A., Bontadina, F., Arlettaz, R., Obrist, M. K., 2013. Landscape connectivity, habitat structure and activity of bat guilds in farmland-dominated matrices. Journal of Applied Ecology 50: 252–261.

Fuentes-Montemayor, E., Goulson, D., Cavin, L., Wallace, J. M., Park, K. J., 2013. Fragmented woodlands in agricultural landscapes: The influence of woodland character and landscape context on bats and their insect prey. Agriculture, Ecosystems and Environment 172: 6–15.

Fuentes-Montemayor, E., Goulson, D., J. M., Park, K. J., 2011. The effectiveness of agri-environment schemes for the conservation of farmland moths: assessing the importance of a landscape-scale management approach. Journal of Applied Ecology 48: 532-542.

Gill, R. M. A., Fuller, R. J., 2007. The effects of deer browsing on woodland structure and songbirds in lowland Britain. Ibis 149: 119-127.

Gilmor, L., in press. MSc thesis, University of Bristol.

Howe, L., Blackstock, T., Burrows, C., Stevens, J., 2005. The habitat survey of Wales. British Wildlife 16: 153–162.

Kokurewicz T., 1995. Increased population of Daubenton's bat (*Myotis daubentonii* (Kuhl, 1819)) (Chiroptera: Vespertilionidae) in Poland. Myotis 32–33: 155–161.

Langton, S. D., Briggs, P. A., Haysom, K., A., 2009. Daubenton's bat distribution along rivers–developing and testing a predictive model. Aquatic conservation: Marine and freshwater ecosystems 20: S45-S54.

Latham, J., Blackstock, T.H., Howe, E.A., 2008. Ecological connectivity in Wales: Planning action to help terrestrial biodiversity respond to habitat fragmentation and climate change. CCW Staff Science Report No. 08/7/1. Countryside Council for Wales.

Limpens, H. J. G. A., Kapteyn, K. 1991. Bats, their behaviour, and linear landscape elements. Myotis 29: 63-71.

Matthews, J.E., Razgour, O. (in press). Discovering Rare Woodland Bats in Wales through Predictive Modelling. CCW Science Report No: 1041, NRW, Bangor.

Matthews, J.E.,Wienhold, M. (in press). Landscapes for Lessers Project - Predictive Model for the Lesser Horseshoe Bat in Wales - CCW Science Report No. 1042. CCW Science Report No: 1042, NRW, Bangor.

Murphy, S. E., Greenaway, F., Hill, D. A., 2012. Patterns of habitat use by female brown long-eared bats presage negative impacts of woodland conservation management. Journal of Zoology 288: 177–183.
Neil, 2013. Survey of agriculture and horticulture: Results for Wales, June 2013. Welsh Government.
Putman, R.J., Edwards, P.J., Mann, J.E.E., Howe R.C., Hill, S.D., 1989. Vegetational and faunal change in an area of heavily grazed woodland following relief of grazing . Biological Conservation 47: 13–32.
Ransome, R. D. 1996. The management of feeding areas for greater horseshoe bats. English Nature.
Razgour, O., Hanmer, J., Jones, G., 2011. Using multi-scale modelling to predict habitat suitability for species of conservation concern: The grey long-eared bat as a case study. Biological Conservation 144: 2922-2930.
Vaughan N, Jones G, Harris S., 1996. Effects of sewage effluent on the activity of bats (Chiroptera: Vespertilionidae) foraging along rivers. Biological Conservation 78: 337–343.
Zeale, M., 2011. Conservation biology of the barbastelle (*Barbastella barbastellus*), applications of spatial modelling, ecology and molecular analysis of diet. PhD thesis, University of Bristol.

10.2 Additional references consulted for literature reviews

Bartonicka, T., Rehak, Z., 2004. Flight activity and habitat use of *Pipistrellus pygmaeus* in a floodplain forest. Mammalia 68: 365-375.
Berge, I., Jones, G., 2008a. Whiskered Bat *Myotis mystacinus*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook 4th Edition. Southampton: The Mammal Society.
Berge, I., Jones, G., 2008b. Brandt's Bat *Myotis brandtii*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook 4th Edition. Southampton: The Mammal Society.
Billington, G., 2000. Radio tracking study of greater horseshoe bats at Mells, Near Frome, Somerset. Peterborough: English Nature
Billington, G., Rawlinson, M.D., 2006. A review of horseshoe bats flight lines and feeding areas. CCW Science Report No. 755. Countryside Council for Wales
Bontadina, F., Schofield, H., Naef-Daenzer, B., 2002. Radio-tracking reveals that lesser horseshoe bats (*Rhinolophus hipposideros*) forage in woodland. Journal of Zoology 258: 281-290.
Boonman, M., 2000. Roost selection by noctule (*Nyctalus noctula*) and Daubenton's bats (*Myotis daubentonii*). Journal of Zoology 251: 385-389.
Boye, P., Dietz, M., 2005. English Nature Research Reports Number 661: Development of good practice guidelines for woodland management for bats. Peterborough: English Nature.
Brandt, G., Blows, L., Linton, D., Paling, N., Prescott, C. 2007. Habitat associations of British bat species on lowland farmland within the Upper Thames catchment area. Centre for Wildlife Assessment and Conservation E-Journal 1: 10-19.
Davidson-Watts I., Walls S., Jones G., 2006. Differential habitat selection by *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* identifies distinct conservation needs for cryptic species of echolocating bats. Biological Conservation 133: 118-127.
Dietz, C., von Helversen, O., Nill, D. 2009. Bats of Britain, Europe and Northwest Africa. London: A. & C. Black Publishers Ltd.

Downs N.C., Racey, P.A., 2006. The use by bats of habitat features in mixed farmland in Scotland. Acta Chiropterologica 8: 169-185.
Entwistle, A.C., Swift, S.M., 2008. Brown Long-eared Bat *Plecotus auritus*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook, 4th Edition. Southampton: The Mammal Society.
Fitzsimmons, P., Hill, D., Greenaway F., 2002. Patterns of habitat use by female Bechstein's bats (*Myotis bechsteinii*) from a maternity colony in a British woodland. Brighton: University of Sussex
Glendell, M; Vaughan, N., 2002. Foraging activity of bats in historic landscape parks in relation to habitat composition and park management. Animal Conservation 5:309-316.
Greenaway, F., 2004. Advice for the management of flightlines and foraging habitats of the barbastelle bat *Barbastella barbastellus*. Peterborough: English Nature.
Greenaway, F., Hill, D., 2004. English Nature Research Report No 658: Woodland management advice for Bechstein's bat and barbastelle bat. Peterborough: English Nature.
Hill, D.A., Greenaway, F., 2008. Conservation of bats in British woodlands. British Wildlife 19: 161-169.
Mackie, I.J., Racey, P.A., 2008. Noctule *Nyctalus noctula*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook, 4th Edition. Southampton: The Mammal Society
Nicholls, B., Racey P.A., 2006. Habitat selection as a mechanism of resource portioning in two cryptic bat species *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*. Ecography 29: 697-708.
Oakeley, S.F., Jones, G., 1998. Habitat around maternity roosts of the 55 kHz phonic type of pipistrelle bats (*Pipistrellus pipistrellus*). Journal of Zoology 245: 222-228.
Ransome, R.D., 1997. The management for greater horseshoe bat feeding areas to enhance population levels: English Nature Research Reports Number 241. Peterborough: English Nature.
Richardson, P.W., Waters, D., Waters, R., 2008. Daubenton's bat *Myotis daubentonii*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook, 4th Edition. Southampton: The Mammal Society.
Robinson, M.F., Stebbings, R.E., 1997. Home range and habitat use by the serotine bat, *Eptesicus serotinus*, in England. Journal of Zoology 243: 117-136.
Ruczynski, I., Bogdanowicz, W., 2008. Summer roost selection by tree-dwelling bats *Nyctalus noctula* and *N. leisleri*: A multiscale analysis. Journal of Mammalogy 89: 942-951.
Russ, J.M., Briffa, M., Montgomery, W.I., 2003. Seasonal patterns in activity and habitat use by bats (*Pipistrellus spp.* and *Nyctalus leisleri*) in Northern Ireland, determined using a driven transect. Journal of Zoology 259: 289-299.
Schofield, H., Messenger, J., Birks, J., Jermyn, D., 2003. Foraging and Roosting Behaviour of Lesser Horseshoe Bats at Ciliau, Radnor. Ledbury: The Vincent Wildlife Trust
Schofield, H., Morris, C., 2000. Ranging behaviour and habitat preferences of female Bechstein's bat, *Myotis bechsteinii* (Kuhl, 1818), in summer. Herefordshire: The Vincent Wildlife Trust.
Schofield, H.W., 2008. The Lesser Horseshoe Bat Conservation Handbook. Ledbury: The Vincent Wildlife Trust.

Schofield, H.W., Greenway, F., 2008. Bechstein's Bat *Myotis bechsteinii*. In Harris, S., Yalden, D.W. (eds.) 2008. Mammals of the British Isles: Handbook, 4th Edition. Southampton: The Mammal Society.

Simon, M., Hüttenbügel, S., Smit-Viergutz, J., 2004. Ecology and Conservation of Bats in Villages and Towns. Bonn: Bundesamt für Naturschutz.

Smith, P.G., Racey, P.A., 2005. The itinerant Natterer: physical and thermal characteristics of summer roosts of *Myotis nattereri* (Mammalia: Chiroptera). Journal of Zoology 266: 171–180

Vaughan, N., Jones, G. & Harris, S., 1997. Habitat use by bats (Chirpotera) assessed by means of a broad-band acoustic method. Journal of Applied Ecology 34: 716-730

Warren, R.D., Waters, D.A., Altringham, J.D., Bullock, D.J., 2000. The distribution of Daubenton's bats (*Myotis daubentonii*) and pipistrelle bats (*Pipistrellus pipistrellus*) (Vespertilionidae) in relation to small-scale variation in riverine habitat. Biological Conservation 92: 85-91.

Zeale, M., 2009. Barbastelles in the Landscape: Ecological Research and Conservation in Dartmoor National Park. Report for Dartmoor National Park/ SITA Trust.

11 Appendices

11.1 Appendix I. Data archive appendix

No data outputs were produced as part of this project.

11.2 Appendix II Review of methods used to assess habitat area occupied by a species

Methods used to assess the area of habitat occupied by a species in previous Article 17 reporting rounds. The reporting round in question is given under the country name.

[a] Countries which made individual species assessments publically available. For these countries only methods used to assess habitat area for bats are considered.

Method	Wales[a] 2007-2012	England[a] 2007-2012	Scotland[a] 2007-2012	Northern Ireland[a] 2007-2012	Ireland[a] 2007-2012	Bulgaria 2007-2012	Belgium 2001-2006	Poland 2001-2006
Area of occupied habitat calculated by identifying the habitat requirements of the species and summing the known area of these habitats.			✓		✓		✓	✓
Area of occupied habitat taken to be equivalent to the area encompassed by the range or distribution of the species.	✓	✓	✓		✓		✓	
Area of occupied habitat taken as equivalent to the area of suitable habitat estimated using a habitat suitability model.				✓	✓	✓		
Area of occupied habitat derived from intensive survey of all known populations							✓	

11.3 Appendix III. Phase 1 habitat types and their suitability for barbastelle

Phase 1 Survey for Wales habitat types classified according to their suitability for barbastelle. Definitions of the suitability categories used are given in Section 2.3.

Habitat code	Habitat type	Suitability
Woodland and scrub		
A.1.1.1	semi-natural broadleaved woodland	Preferred
A.1.1.2	planted broadleaved woodland	Preferred
A.1.2.1	semi-natural coniferous woodland	Used
A.1.2.2	planted coniferous woodland	Used
A.1.3.1	semi-natural mixed woodland	Preferred
A.1.3.2	planted mixed woodland	Preferred
A.2.1	dense scrub	Used
A.2.2	scattered scrub	Used
A.3.1	scattered broadleaved trees	Preferred
A.3.2	scattered coniferous trees	Used
A.3.3	scattered mixed trees	Preferred
A.4.1	felled broadleaved woodland	Used
A.4.2	felled coniferous woodland	Used
A.4.3	felled mixed woodland	Used
Grassland and marsh		
B.1	acid grassland	Preferred
B.1.1	unimproved acid grassland	Preferred
B.1.2	semi-improved acid grassland	Preferred
B.2.1	unimproved neutral grassland	Preferred
B.2.2	semi-improved neutral grassland	Preferred
B.3.1	unimproved calcareous grassland	Preferred
B.3.2	semi-improved calcareous grassland	Preferred
B.4	improved grassland	Used
B.5	marshy grassland	Preferred
B.5.1	marshy grassland *Juncus* dominated	Preferred
B.5.2	marshy grassland *Molinia* dominated	Preferred
Tall herb and fern		
C.1.1	Bracken	Used
C.1.2	scattered bracken	Used
C.2	upland species rich ledges	Used
C.3.1	tall ruderal herb	Used
C.3.2	non-ruderal herb and fern	Used
Heathland		
D.1.1	dry acid heath	Used
D.1.2	dry basic heath	Used

D.1.3	scattered dry heath	Used
D.2	wet heath	Used
D.3	lichen/bryophyte heath	Used
D.5	dry heath/acid grassland mosaic	Used
D.6	wet heath/acid grassland mosaic	Used
D.7	basic dry heath/calcareous grassland mosaic	Used
Mire		
E.1.6.1	blanket bog	Used
E.1.6.2	raised bog	Used
E.1.7	wet modified bog	Used
E.1.8	dry modified bog	Used
E.2	flush and spring	Used
E.2.1	acid/neutral flush	Used
E.2.2	basic flush	Used
E.2.3	bryophyte-dominated spring	Used
E.3	Fen	Used
E.3.1	valley mire	Used
E.3.1.1	modified valley mire	Used
E.3.2	basin mire	Used
E.3.2.1	modified basin mire	Used
E.3.3	flood-plain mire	Used
E.3.3.1	modified flood plain mire	Used
E.4	bare peat	Used
Swamp, marginal and inundation		
F.1	Swamp	Used
F.1.1	scattered swamp	Used
F.2.2	inundation vegetation	Used
Open water		
G.1	standing water	Preferred
G.2	running water	Preferred
Coastland		
H.1.1	intertidal mud/sand	Avoided or unknown
H.1.2	intertidal cobbles/shingle	Avoided or unknown
H.1.3	intertidal rocks/boulders	Avoided or unknown
H.2.4	scattered salt marsh plants	Used
H.2.6	salt marsh	Used
H.3.1	mud/sand above mean high water	Avoided or unknown
H.3.2	shingle/gravel above mean high water	Avoided or unknown
H.4	rocks/boulders above mean high	Avoided or unknown

	water	
H.6.4	dune slack	Used
H.6.5	dune grassland	Used
H.6.6	dune heath	Used
H.6.7	dune scrub	Used
H.6.8	open dune	Used
H.8.1	hard cliff	Used
H.8.2	soft cliff	Used
H.8.4	coastal grassland	Used
H.8.5	coastal heath	Used
H.8.6	coastal heath/coastal grassland mosaic	Used
Rock exposure and waste		
I.1	natural rock exposure	Avoided or unknown
I.1.1	inland cliff	Avoided or unknown
I.1.1.1	acid/neutral inland cliff	Avoided or unknown
I.1.1.2	basic inland cliff	Avoided or unknown
I.1.2	Scree	Avoided or unknown
I.1.2.1	acid/neutral scree	Avoided or unknown
I.1.2.2	basic scree	Avoided or unknown
I.1.3	limestone pavement	Avoided or unknown
I.1.4	other rock exposure	Avoided or unknown
I.1.4.1	acid/neutral rock	Avoided or unknown
I.1.4.2	basic rock	Avoided or unknown
I.1.5	Cave	Avoided or unknown
I.2.1	Quarry	Avoided or unknown
I.2.2	Spoil	Avoided or unknown
I.2.3	Mine	Avoided or unknown
I.2.4	refuse-tip	Avoided or unknown
Miscellaneous		
J.1.1	Arable	Avoided or unknown
J.1.2	amenity grassland	Avoided or unknown
J.1.3	ephemeral/short perennial	Avoided or unknown
J.1.4	introduced scrub	Avoided or unknown
J.1.5	Gardens	Used
J.3.4	caravan site	Avoided or unknown
J.3.5	sea-wall	Avoided or unknown
J.3.6	Buildings	Avoided or unknown
J.3.7	track (not comprehensively digitised)	Avoided or unknown
J.4	bare ground	Avoided or unknown

11.4 Appendix IV. Indicators of habitat quality for bat species

Indicators of habitat quality for bat species assessed as part of the Article 17 reporting process in Wales. A strong positive relationship is indicated by '++', a positive relationship by '+', a negative relationship by '-'and an equivocal relationship by '+/-'.

Indicator of habitat quality	Common pipistrelle	Soprano pipistrelle	Nathusius' pipistrelle	Brown long-eared bat	Greater horseshoe bat	Lesser horseshoe bat	Barbastelle	Daubenton's bat
Prey availability								
Abundance of aerial invertebrates	+	+	+	+	+	+	+	+
Abundance of nocturnal Lepidoptera				++	+	+	++	
Abundance of Colepotera				+	+			
Abundance of Diptera	+	+	+	+		++		+
Roost availability								
Availability of suitable roost sites in built structures	+	+	+	+	++	++	+	+
Density of trees with loose bark	+	+	+	+			++	
Density of trees with cracks	+	+	+	+				+
Density of trees with rot or woodpecker holes	+	+	+	+				+
Density of veteran/senescing, dead or damaged trees	+	+	+	+			+	+
Proximity of water to the roost		+	+	+				+
Foraging habitat								
Extent of broadleaved woodland	+	+	+	+	+	+	+	+
Extent of old growth/ancient woodland					+	+	+	
Extent of wet woodland		+	+			+	+	
Extent of riparian vegetation	+	+	+			+	+	+
Extent of unimproved grassland	+				+		+	
Extent of pasture	+				+	+		
Extent of wetlands and wet meadows	+	+				+	+	
Extent of parkland with scattered trees	+	+	+	+		+	+	+
Extent of open water		+	+					+

Continued overleaf

Indicator of habitat quality	Common pipistrelle	Soprano pipistrelle	Nathusius' pipistrelle	Brown long-eared bat	Greater horseshoe bat	Lesser horseshoe bat	Barbastelle	Daubenton's bat
Characteristics of woodland								
Presence of a structurally diverse woodland edge	+	+	+	+	+	+	+	
Structural diversity of woodland				+		+		
Understorey density	-			+		+		
Understorey species richness								
Woodland canopy cover	+							
Abundance of oak trees							+	+
Number of connective features linking woodland patches		+			+	+	+	
Abundance of invasive woodland plant species				-		-	-	
Grazing pressure within woodlands	+			-		-		
Woodland patch size	+						+	
Woodland patch isolation		+						
Connective landscape features								
Density of connective landscape features	+	+	+	+	+	+	+	+
Density of trees in connective features		+		+				+
Hedgerow height	+	+			+	+		
Other								
Abundance of in-field trees				+				
Lighting of commuting routes and foraging sites					-	-		
Number of woodland or in-field ponds, ditches or streams	+	+	+	+		+	+	+
Use of long acting endectocides in livestock			-		-	-		
Water quality	+	+						+/-
Cover of aquatic plants on the surface of water bodies								-

Continued overleaf

Indicator of habitat quality	Natterer's bat	Bechstein's bat	Whiskered bat	Brandt's bat	Noctule	Leisler's bat	Serotine
Prey availability							
Abundance of aerial invertebrates	+	+	+	+	+	+	+
Abundance of nocturnal Lepidoptera		+	+	+	+	+	
Abundance of Colepotera	+				+		++
Abundance of Diptera	+	+	+	+	++	++	
Roost availability							
Availability of suitable roost sites in built structures	+		+	+		+	++
Density of trees with loose bark			+	+			
Density of trees with cracks	+	+	+	+		+	
Density of trees with rot or woodpecker holes	+	+	+	+	++	+	
Density of veteran/senescing, dead or damaged trees	+	+	+	+	+	+	
Proximity of water to the roost							
Foraging habitat							
Extent of broadleaved woodland	+	+	+	+	+	+	+
Extent of old growth/ancient woodland	+	+		+			
Extent of wet woodland	+	+		+			
Extent of riparian vegetation	+	+	+	+		+	+
Extent of unimproved grassland	+		+		+	+	+
Extent of pasture	+		+		+	+	+
Extent of wetlands and wet meadows	+				+	+	+
Extent of parkland with scattered trees	+		+	+	+	+	+
Extent of open water	+				+	+	+

Continued overleaf

Indicator of habitat quality	Natterer's bat	Bechstein's bat	Whiskered bat	Brandt's bat	Noctule	Leisler's bat	Serotine
Characteristics of woodland							
Presence of a structurally diverse woodland edge	+		+	+	+	+	+
Structural diversity of woodland		+		+			
Understorey density	+	+	+	+			
Understorey species richness		+					
Woodland canopy cover		+					
Abundance of oak trees		+			+		
Number of connective features linking woodland patches		+					
Abundance of invasive woodland plant species		-			-		
Grazing pressure within woodlands	-	-	-	-			
Woodland patch size		+			+		
Woodland patch isolation				-			
Connective landscape features							
Density of connective landscape features	+	+	+	+			
Density of trees in connective features	+	+					
Hedgerow height							
Other							
Abundance of in-field trees	+						
Lighting of commuting routes and foraging sites							
Number of woodland or in-field ponds, ditches or streams	+	+					+
Use of long acting endectocides in livestock	-		-				-
Water quality	+				+		
Cover of aquatic plants on the surface of water bodies							

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