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Development of good practice guidelines for woodland management for bats

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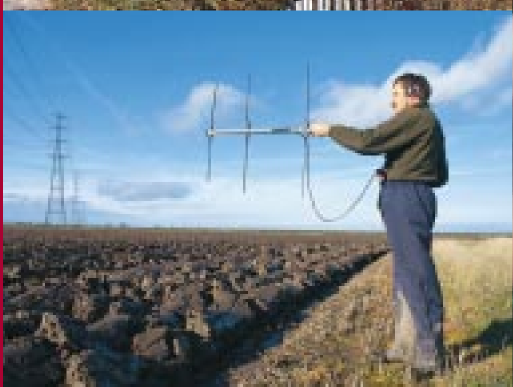


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Development of good practice guidelines for woodland management for bats

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Commissioned by: The Bat Conservation Trust

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Preamble

This report gives an overview of the current state of knowledge on the biology and ecology of Central European bat species in woodland. It is based on an extensive evaluation of the literature in addition to unpublished secondary sources. The work of the Intersessional Working Group of the EUROBATS Agreement that deals with current forestry practices and the conservation of bats in European woodland is an example of this.

Many uncited results originate from our own technical experience as bat specialists and intensive field research, carried out over more than ten years. Some extensive surveys in large woodlands have been carried out in the context of impact assessments or management of protected areas, for example in national parks, forest reserves, or Natura 2000 sites.

This report shall be of use as a reference for employees in forest administrations as well as for voluntary and professional bat conservationists. The long-lasting cooperation with forest wardens was a great help to us when choosing the content of the report. Meanwhile we have trained more than 700 employees of forest administrations in the course of further education to give them a better understanding of the life of bats in woodland.

Dr. Peter Boye and Markus Dietz

Contents

1. Legal aspects

There are three international treaties requiring the legal protection of bats and their habitats in Europe: The EU Habitats Directive, the Berne Convention and the EUROBATS Agreement. EU Member States must implement the regulations of the Habitats Directive, which cover obligations and recommendations from the Berne Convention and the EUROBATS Agreement at the same time. Non-EU Member States that have joined the Berne Convention or the EUROBATS Agreement (Table 1) should also implement the legal obligations listed by those treaties, as they accepted them through their accession.

The implementation of the relevant international obligations must be transposed into national law in all three cases. There is very little information currently available about specific legislation concerning bat conservation in European countries and even less about cases of prosecution. For this reason, we concentrate on a summary of the relevant regulations, highlight the current dispute within the EU about the interpretation of Article 12 of the Habitats Directive, and report about the situation in Germany as an example of national implementation.

1.1 The Berne Convention

Article 6 of the 'Convention on the Conservation of European Wildlife and Natural Habitats' (Berne Convention) reads:

> "Each Contracting Party shall take appropriate and necessary legislative and administrative measures to ensure the special protection of the wild fauna species specified in Appendix II. The following will in particular be prohibited for these species:
>
> a. all forms of deliberate capture and keeping and deliberate killing;
>
> b. the deliberate damage to or destruction of breeding or resting sites;
>
> c. the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation, insofar as disturbance would be significant in relation to the objectives of this Convention; ..."

Appendix II lists strictly protected fauna species, including "Microchiroptera, all species except *Pipistrellus pipistrellus*".

1.2 The EUROBATS Agreement

The 'Agreement on the Conservation of Populations of European Bats' (EUROBATS) was negotiated under the 'Convention for the Conservation of Migratory Wild Species' (Bonn Convention) and came into force in January 1994. The legal protection of bats and their habitats are given in Article III as fundamental obligations:

> "1. Each Party shall prohibit the deliberate capture, keeping or killing of bats except under permit from its competent authority.

“2. Each Party shall identify those sites within its own area of jurisdiction which are important for the conservation status, including for the shelter and protection, of bats. It shall, taking into account as necessary economic and social considerations, protect such sites from damage or disturbance. In addition, each Party shall endeavour to identify and protect important feeding areas for bats from damage or disturbance.”

The Agreement covers all European bat species except the non-migratory endemics of the Atlantic islands.

The fundamental obligations cited above are fulfilled by national law in accordance with the EU Habitats Directive (see following chapter). For this reason all EUROBATS Parties which are EU Member States (Table 1) must have an appropriate national legislation, reviewed by the European Commission. This is also the case in Bulgaria and Romania due to legal preparations for their EU accession in 2008.

The situation in non-EU Member States of EUROBATS is as follows:

Albania All bat species except the common pipistrelle *Pipistrellus pipistrellus* are legally protected. A modern Law on the Protection of Biodiversity is awaiting approval.

Croatia All bat species are legally protected from capturing, keeping, killing, ringing etc. Cave fauna in general has the same protection status but there are no specific regulations concerning bat roosts, for example in trees. To consider important bat habitats more carefully, general measurements for forestry practice will be taken as part of the Nature Protection Law, which is in preparation.

Georgia The disturbance and taking of bats is prohibited by law, but no considerations are given to habitats that are important to bats, such as roost trees.

FYR Macedonia Macedonian law does not presently protect bats, but the matter will be covered by a new Framework Law for Nature Protection and a new Law for Animal Protection. It is intended to harmonize national legislation with EU Directives.

Moldova 18 bat species are protected by the Law on Animal Kingdom. Kuhl’s pipistrelle *Pipistrellus kuhlii*, the soprano pipistrelle *Pipistrellus pygmaeus* and the grey long-eared bat *Plecotus austriacus* were recently recorded in Moldova and are not yet considered by any legal acts. Insufficient consideration is given to habitats that are important to bats, such as roost trees.

Monaco A framework law on species protection is being prepared. The Principality is completely urbanized so there is no forestry management in Monaco.

Ukraine A number of legal environmental acts concerns bat species. They are protected by law and capturing or killing them is prohibited with further restrictions on those 12 species listed in the Red Data Book of Ukraine. An Action Plan to fully implement EUROBATS has been devised on behalf on the Minister of Ecology and Natural Resources.

During the 4th Meeting of the Parties of EUROBATS in Sofia in 2003, Resolution 4.4 ‘Bat Conservation and Sustainable Forest Management’ was adopted. The Meeting of the Parties to the Agreement decided that the contracting Parties (Member States) should identify key areas and key elements (for example roost trees) for bats in woodlands and encouraged Parties to protect, restore and enhance, where appropriate, such key elements and key areas with special emphasis to unfragmented woodlands, wet forests, undegraded ancient woodlands and undisturbed core areas. The Parties were further encouraged to combine forestry management with bat conservation on the landscape level. This includes legal and voluntary conservation of key areas and key elements.

1.3 The EU Habitats Directive

Article 12 (1) of the 'Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora' (Habitats Directive) states:

> "Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range, prohibiting:
>
> a) all forms of deliberate capture or killing of specimens of these species in the wild;
>
> b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration;
>
> c) deliberate destruction or taking of eggs from the wild;
>
> d) deterioration or destruction of breeding sites or resting places."

Annex IV a) of the Habitats Directive names the animal species of Community Interest which should be strictly protected, inter alia "Microchiroptera – all species". In accordance with Article 2 this covers all bat species occurring "in the European territory of the Member States to which the Treaty applies". Currently, these are all European bats including the endemic species of the Atlantic islands, but with the exception of Schaub's myotis *Myotis schaubi* and the eastern barbastelle *Barbastella leucomelas*.

Article 12 was relevant in case file 103/00 at the European High Court dealing with the disturbance of nesting loggerhead turtles *Caretta caretta* by motorbikes and boats. On 30 January 2002 the Court decided that a deliberate act does not necessarily need to aim at a particular effect, i.e. the disturbance of animals. If the person knows that protected species occur at the site where he or she performs harmful activities, it is enough to assume a certain intention. As a consequence, the disturbance of bats or destruction of their roosts is considered deliberate if the person knows about the presence of the species strictly protected by the Habitats Directive, even if it is not their aim to harm bats.

The decision of the European High Court initiated intensive ongoing discussions within the EU Habitat Committee and at a high political level in many EU countries. It is not yet clear how to proceed with land use practices like woodland management, which are connected to measures that might have impacts on strictly protected species (for Germany see chapter 1.4). Views on this problem are very different in various countries and depend very much on either the role of forestry and land management within the countries' economy or the role of biodiversity conservation in governmental policies.

To drive the discussions forwards, the EU Habitats Committee established a Working Group on Article 12. A recent discussion paper by Deborah Procter (JNCC, UK) was distributed by the group (August 2004) to propose common definitions of breeding sites and resting places, in accordance with Article 12.1.d of the Habitats Directive. Following this paper, in the field of bat biology, it is proposed to define 'breeding' as mating and giving birth to young, and 'breeding site' as the area needed to mate and give birth in and the associated structures needed for territorial definition and defence. Breeding sites may include areas required for courtship, mating, parturition, and occupation by young dependent on the parturition site. 'Resting places' are defined as areas essential to sustain an animal or group of animals when they are not active, including during periods of hibernation and migration. Resting places may include one or more structures and habitat features required for resting, sleeping or recuperation (e.g. roosts). They may be used regularly, periodically or seasonally and so will need to be maintained and protected even when not occupied on specific occasions (e.g. bat hibernacula), and may be needed to provide ecological support for individuals of migrating species to enable them to rest and recuperate ready for the next stage of their journey.

Table 1 International treaty membership of European countries

Country	European Community	EUROBATS	Berne Convention[1]	MCPFE[1]
Albania		●	●	●
Andorra			●	●
Armenia				
Austria	●		●	●
Azerbaijan			●	
Belarus				●
Belgium	●	●	●	●
Bosnia-Herzegovina				●
Bulgaria		●	●	●
Croatia		●	●	●
Cyprus	●		●	●
Czech Republic	●	●	●	●
Denmark	●	●	●	●
Estonia	●		●	●
Finland	●	●	●	●
France	●	●	●	●
Georgia		●		●
Germany	●	●	●	●
Greece	●		●	●
Holy Sea				●
Hungary	●	●	●	●
Iceland			●	●
Ireland	●	●	●	●
Italy	●	●	●	●
Latvia	●	●	●	●
Liechtenstein			●	●
Lithuania	●	●	●	●
Luxembourg	●	●	●	●
Macedonia FYR		●	●	
Malta	●	●	●	●
Moldova		●	●	●
Monaco		●	●	●

Country	European Community	EUROBATS	Berne Convention[1]	MCPFE[1]
The Netherlands	●	●	●	●
Norway		●	●	●
Poland	●	●	●	●
Portugal	●	●	●	●
Romania		●	●	●
Russian Federation				●
San Marino				
Serbia & Montenegro				●
Slovakia	●	●	●	●
Slovenia	●	●	●	●
Spain	●		●	●
Sweden	●	●	●	●
Switzerland			●	●
Turkey			●	●
Ukraine		●	●	●
United Kingdom	●	●	●	●

[1]= The EC is also member

MCPFE = Ministerial Conference for the Protection of Forests in Europe

1.4 Case study: Legal bat protection in Germany

In Germany there is a Federal Nature Conservation Act which gives a framework for regional legislation on nature conservation passed by the 16 Federal Länder (regions). The definition of specially and strictly protected species and the Section on protection and management of wild fauna and flora species of the Federal Act implements the international legal obligations in species conservation and is binding for the Länder (region). The European bat species are specially and strictly protected in Germany as they belong to the "fauna and flora species listed in Annex IV of Council Directive 92/43/EEC" (§10 (2) 10. and 11.)." "It is prohibited, to pursue, capture, injure or kill any wild specimen of specially protected fauna species, or to remove from the wild, damage, or destroy any forms of their life-cycle, their nesting or breeding sites, other living quarters or inhabited sites or any other places of refuge" (§42 (1) 1.). But "the prohibitions specified in Article 42 paragraphs 1 and 2 shall not apply if the actions are associated with the use of land for agricultural, forestry and fishery purposes in the framework of and in line with the terms of good practice..." (§43 (4)). However, this wording has been valid since March 2002 and the terms of good practice in forestry management have yet to be defined.

Because of the European High Court decision on the loggerhead turtle proceedings (see chapter 1.3) and related activities of the European Commission an argument is going on among the Federal Government and the Länder (regions). Currently the legal situation in the case of woodland management measures that have an impact on bat roost in trees is unclear. While foresters rely on a general exception of woodland management from the prohibitions in favour of specially protected animals, the legislation has to be interpreted in a different way. In accordance with recent decisions of the Administrative Court of the Land of Hesse in dealing with comparable cases it should be necessary to apply for a specific exemption from the species conservation regulations in each case of cutting roost trees in a bat habitat.

In the past there were many occurrences of bat roost destruction due to logging. Many cases documented impacts on large hibernation colonies of the noctule *Nyctalus noctula*. There are also publications on regional conservation problems due to the harvest of well known roost trees by foresters. However, we cannot report any impeachment or prosecution of forestry managers or other people being responsible for the damage to a tree roost.

1.5 Woodland management in accordance with international treaties on bat protection

There are no improved regulations about how woodland management can be carried out without risk of managers being prosecuted for destroying bat roosts. In Germany the use of woodland for silvicultural purposes should have the aim "to progressively establish near-natural forests and to manage these in a sustainable manner without clearfelling. A sufficient proportion of locally adjusted site-specific forest plants shall be attained" (Federal Nature Conservation Act, § 5 (5)).

From our scientific point of view woodland managers act in accordance with roost protection regulations if they fulfil the following two points:

1. Identified roost trees of maternity colonies must not be harvested but maintained undisturbed in the stands.

2. A sufficient number of potential roosts shall be offered to bats as a precautionary measure.

As a rule of thumb 25-30 holes or crevices in trees per woodland hectare are needed. This can be ensured by retaining 7-10 old trees and the same number of younger trees to become the next roost tree generation (Meschede & Heller 2000). Deviations from this rule may occur if the bat fauna present in a forest was investigated and more specific conservation measures are recommended and implemented.

If this number of potential roosts is protected and made available to bats in the long term in a certain area, woodland managers can presume that the animals use some of them. If another roost site is discovered in a logged tree the occurrence of the bat in this tree is considered unpredictable and no prosecution is feasible.

2. Benefits of having bats in woodland

2.1 General ethical and legal aspects including international obligations

Woodlands have specific ecological functions for bats during the year, which may vary in space, time, and according to the particular bat species (Meschede & Heller 2000). Bats are inherent elements of woodland ecosystems. Most European bat species use woodlands as habitats at least during a certain period of the year. Their conservation is taken for granted following a general ethical attitude for the conservation of nature, the sense of the Convention on Biological Diversity, or legal obligations from European agreements and EU or national law.

Since the United Nations Development Programme agreed on "2010 – The Global Biodiversity Challenge" and its target to reduce the current rate of biodiversity loss at the global, regional and national levels the by the year 2010, conservation of woodland fauna in Europe has become even more important as woodlands are the most abundant natural habitat types in Europe where many of the endemic and threatened species live. Bats are an important species group to prove the extent of reaching the 2010 target by woodland management.

2.2 Woodlands and bat abundance in the wider landscape

For bat conservation woodlands always have to be dealt with in connection with the wider landscape because bats in woodlands have many ecological relationships to the wider landscape surrounding the woodlands. Some species roost in woodlands but forage mainly outside (such as the noctule) or at areas within the woodland but without trees such as clearcuts or water bodies (Daubenton's bat *Myotis daubentonii*, whiskered bat *M. mystacinus*, Brandt's bat *M. brandtii*, Leisler's bat *Nyctalus leisleri*). Orchards near woodlands are often visited for feeding by Bechstein's bat *Myotis bechsteinii* and the brown long-eared bat *Plecotus auritus*. Other species prefer roost sites in buildings but forage in woodlands, which they reach by following certain flight paths (such as the greater horseshoe bat *Rhinolophus ferrumequinum,* lesser horseshoe bat *Rhinolophus hipposideros,* the common pipistrelle, and grey long-eared bat). So the abundance of bats in a landscape is highly dependent on the habitat quality of the woodlands as roost and foraging sites. The availability of roosts in buildings, the abundance of arthropods outside woodlands, and the degree of habitat connectivity are also relevant factors for the wider landscape's bat fauna.

2.3 Pest insect predation

As all European bat species forage on arthropods, bats are important insect predators with some benefits to woodland management. The abundance of pest insects may be influenced by bats because bats often accumulate at places where a particular prey species is abundant and consume significant numbers of insects per night, e.g. the noctule consumes 10-15 grams of insects (Meise 1951, Dittrich 1958) and Daubenton's bat about 5-6 grams (4,000-5,000 individual midges) (Dietz 1998). It is doubtful whether bats are able to influence or even reduce population fluctuations in pest insects but at least it is observed that the brown long-eared bat concentrates its foraging activities on a pest butterfly (*Tortrix viridana*) during outbreak years (Kolb 1958).

2.4 Public interests

Bats are fascinating creatures for people, and children in particular are very interested to watch bats in the night. For this reason public bat walks are very popular and at the same time present opportunities to communicate knowledge related to nature conservation or woodland management. Special experience was accumulated in a German bat conservation project when 54 bat walks were held with a total of more than 1,800 participants (Dietz & Weber 2002). Through media reports and personal communication there was a continuously high level of interest in bat walks over four years. Summer excursions were usually fully booked by March or April.

It proved good to start a bat walk with a lecture about bat biology. Many questions can be answered before the observation of bats starts and people can understand more easily what they see later on. When bats leave their roosts or pass the observers, time is usually too short for explanations. But after a theoretical introduction short comments are enough to guide and satisfy people. Of course, a good bat walk needs a limit on the number of participants to what is acceptable for the guiding bat expert. Another precondition for successful bat walks is some knowledge about the local bat fauna and the best areas to watch it. In most cases a survey has to be done well in advance of a public bat event.

If participants of a bat walk have the opportunity to watch bats flying in their natural habitat they will be receptive to information on nature conservation needs or aspects of woodlands management connected to bats. The experience of a successful night walk with bats influences personal attitudes towards bat conservation in the long term. These effects can be improved the more is known by the guide about the bats at a certain locality where the bat walk is done. For this reason and for economic purposes as well, it is useful to visit the same area again and again (Dietz & Weber 2002).

Woodland that is appropriate for regular bat walks will deserve a positive public attitude. Woodland managers may have special opportunities to tell ordinary people about their management measures and consequently find more acceptance in the community.

2.5 Bats as indicators of woodland biodiversity and sustainable management

The conservation of forests has been a global target for around 15 years. From the European perspective the main international events in this process were:

- the establishment of the "Ministerial Conference for the Protection of Forests in Europe" (MCPFE), 1990 in Strasbourg;
- the "UN Conference on Environment and Development" (UNCED) which negotiated the Convention on Biological Diversity (CBD), Agenda 21 and the Forest Declaration, 1992 in Rio de Janeiro;
- the "EU Habitats Directive" coming into force in 1992;
- the establishment of the "Forest Stewardship Council" (FSC) and its system of certifications for wood products, 1993 in Toronto; and
- the establishment of the "Pan-European Biological and Landscape Diversity Strategy" (PEBLDS) by the Ministerial Conference "Environment for Europe", 1995 in Sofia.

Global discussions about the best ways to enhance sustainability in woodland management have focussed on criteria and indicators since 1995. Some important decisions were made in 1998:

- the 4th CBD Conference of Parties concluded a work programme on the biodiversity of forests (Resolution IV/7), which covered the development of criteria and indicators for biodiversity;
- the 3rd MCPEF concluded pan-European criteria and indicators for sustainable forestry (Resolution L2) and a Joint Work Programme of MCPFE and PEBLDS on the conservation of biodiversity in European woodlands;
- the 4th Ministerial Conference "Environment for Europe" also concluded the Joint Work Programme of MCPFE and PEBLDS;
- the 2nd EUROBATS Meeting of the Parties recommended the development of guidelines for bat-friendly forestry practices (Resolution MOP2/4 Element 2); and

- the European Commission initiated the FAIR-Project "Indicators for monitoring and evaluation of forest biodiversity in Europe, BEAR" to identify key factors of European forest types, develop a strategy for the development of appropriate indicators for forest biodiversity and propose biodiversity evaluation tools.

During subsequent years the development of indicators for biodiversity or sustainability was intensified under the CBD (SBSTTA), among European governments (MCPFE and Governmental Conference "Biodiversity in Europe"), within the European Union (ECNC and EEA) and by the EUROBATS Agreement. Currently it is agreed by almost all of these organisations and processes that animal species shall be used as indicator organisms. Reviews of the progress made and the indicators in use so far were published by the European Environmental Agency (Delbaere 2002) and the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity (SBSTTA) (Document UNEP/CBD/SBSTTA/9/10). However, there is no operational proposal as to which species are appropriate and how a species-based indicator for biodiversity or sustainability in forests may be defined. That said, however, Member States of the EUROBATS Agreement (which are almost the same as in many other European treaties (Table 1)), decided with Resolution No. 4.4 during the 4th Meeting of the Parties in Sofia in 2003 that the EUROBATS Advisory Committee should instigate the investigation and, if appropriate, the development of the use of bats as indicators for sustainable forestry and biodiversity in certain habitats in Europe. To fulfil this direction until the next Meeting of the Parties in 2006 the Advisory Committee established a working group. This group will clarify the state of knowledge about bats being representative of non-bat biodiversity richness.

In conclusion one may presume that bats will be used as indicator organisms in woodlands in some way in the future. For this reason it is recommended that woodland managers start surveys of forest bat fauna as soon as possible and improve the populations' status by appropriate conservation measures.

2.6 Incentive schemes

There are many programmes to fund conservation measures or environmentally responsible behaviour in agriculture in European countries. In some countries it is also possible to make such funds available to woodland managers. In general the available economic instruments are:

- direct investments in government implemented projects in public forests;
- incentive programmes to private forest owners; and
- public/private partnership.

In theory, bat-friendly forestry practices can be supported by the appropriate economic instruments at least in Sweden, Finland, Germany, and the Czech Republic. However, the optimal choice of instruments and implementation mechanism is a complex matter of trade-offs between ecological values or bat conservation targets and socio-economic considerations. Tailoring the policy mechanisms to suit the conservation requirements in a cost-effective and socially acceptable manner is a challenging task for the policy makers. On the other hand, new management practices in woodlands with reference to bat conservation will need financial support as incentives generally play an important role in the decisions of central European forest owners and managers to innovate. They perceive financial incentives in form of subsidies as one of the major factors fostering innovation.

Related aspects were recently discussed during the international conference "Evaluating Forestry Incentive and Assistance Programmes in Europe – challenges to improve policy effectiveness", held in October 2004 in Warsaw (http://www.efi.fi/events/extra/2004/effe_workshop/). In the near future an overview will be published on the types of woodland management activities supported, the level of financing, beneficiaries and outputs of forestry incentive and assistance programmes in Europe, including an evaluation in a comparative perspective.

3. Woodland bat lifestyles

3.1 Greater horseshoe bat *Rhinolophus ferrumequinum*

Forest habitats: Deciduous forests are used as foraging areas (important in spring, only forest edges in summer). Appropriate underground hibernation sites should exist close to summer habitats.

Summer roosts: The greater horseshoe bat prefers warm places. Summer roosts are in caves, mines or buildings and may have daily temperatures of about 10-37 °C. North of the Alps maternity roosts number up to several hundred animals. They are mainly in large lofts or church towers. Such roost sites must not have draughts, but need not be entirely dark (Pir and others 2004). In southern Europe caves are preferred as roost sites (Bulgaria: Pandurska 1997, Italy: Spagnesi and others 2000, Spain and Portugal: Benzal and others 1991). Summer roosts often have sufficient diversity to allow animals to choose their resting places along a gradient of temperature and humidity. Males use summer roosts in small groups or individually (Schober 1998, Gaisler 2001).

In summer roosts the species is frequently associated with Geoffroy's bat *Myotis emarginatus* (Pir and others 2004).

Winter roosts: Winter roosts are exclusively underground in caves, mines, fortresses or cellars. They must have high humidity and temperatures of 5-12 °C to be suitable for the species (Pir and others 2004).

The greater horseshoe bat does not migrate over large distances. Summer and winter roosts are usually at a distance of 20-35 kilometres from one another, exceptionally up to 100 kilometres (Pir and others 2004). In single cases marked individuals were recorded as flying over 320 kilometres (Hungary) and 500 kilometres (France) (Gaisler 2001).

In most winter roosts other bat species that hibernate in underground habitats occur as well, especially those of the genus *Myotis* and *Plecotus* (Pir and others 2004).

Other roosts: Besides their summer and winter roosts greater horseshoe bats use certain caves or buildings as intermediate roost sites, which they regularly visit for a short time during spring and autumn (Gaisler 2001).

Foraging areas: Central European specimens mainly forage in cultivated landscapes with plenty of habitat structure and low management intensity. Pasture with high orchard trees, ancient trees or hedgerows is preferred. In spring the majority of the population forages in deciduous forests; in summer in open fields, at trees or bushes along streams or creeks, along forest edges, at warm slopes or near villages (Beck & Schelbert 1999, Gaisler 2001, Geiger 1996, Bontadina 2002, Meschede & Heller 2000, Schober 1998). The bats regularly visit special locations in their foraging areas where they take a small break from flying (Geiger 1996).

Individuals use several foraging areas of 6-7 hectares each (Pir and others 2004). In Northern Bavaria (Germany) they visit 11-25 of such areas per night (Geiger 1996). Specimens from one colony sometimes forage in the same places, so that Bontadina (2002) could estimate the whole foraging area of a colony of 150 animals by telemetric observation of 15 individuals.

Foraging areas are selected close to the roost sites or at distances up to 14 kilometres (Geiger 1996, Beck & Schelbert 1999, Meschede & Heller 2000, Bontadina 2002, Bontadina and others 1997).

3.2 Lesser horseshoe bat *Rhinolophus hipposideros*

Forest habitats: Deciduous forests are important foraging habitats. Appropriate underground hibernation sites should exist close to summer habitats.

Summer roosts: In Central Europe summer roosts are mainly in undisturbed lofts of houses. Sometimes maternity colonies occur in unused rooms and warm cellars of houses or in karst caves (Biedermann & Boye 2004, Kulzer 2003, Meschede & Heller 2000, Roer & Schober 2001, Interessengemeinschaft Fledermausschutz und –forschung Thüringen e.V. 2002). Roosts are usually situated close to woodland or a park. If this is not the case a system of continuous linear landscape elements, such as hedges, ecotones or walls, provide guidance to the bats when flying to their foraging areas (Biedermann 1999, Motte & Libois 2002).

Winter roosts: Undisturbed hibernation sites in underground caves, mines or cellars must be available at a maximum distance of 30 kilometres from the summer roosts (Biedermann & Boye 2004).

Seasonal migrations over a distance of 5-30 kilometres occur regularly to change between summer and winter habitats. The longest distance recorded so far is 146 kilometres (Schober 1998, Roer & Schober 2001).

In most winter roosts other bat species that hibernate underground are also present, especially those from the genus *Myotis* und *Plecotus*.

Foraging areas: Woodlands play a predominant role as foraging habitats of the species (Bontadina and others 2002, Holzhaider and others 2002, Motte & Libois 2002), especially in spring when the lesser horseshoe bat nearly exclusively forages there (Bontadina 2002). In Germany foraging habitats near maternity colonies of more than 50 adults comprise more than 20% deciduous forests (Biedermann 1999).

Individual home ranges of females from maternity colonies are between 12 and 53 hectares in size (Bontadina and others 2002). The 29 female adults of the maternity colony from

Herrenchiemsee Island in Bavaria (Germany) use the whole of the 230 hectare highly structured island (Meschede & Heller 2000).

Foraging areas are close to the summer roosts (distances up to 4.2 kilometres) and the animals spend about half of their time of activity within a circle around their roost site with the radius of 600 metres (Bontadina 2002, Holzhaider and others 2002).

3.3 Daubenton's bat *Myotis daubentonii*

Forest habitats: Forests are the main summer roost sites and are also used for foraging, but the most important foraging areas are ponds and rivers and other water bodies.

Summer roosts: Woodlands are most important as roost sites for Daubenton's bat, especially if they are close to water bodies. Summer roosts are predominantly in trees, sometimes in wall crevices in buildings or underneath bridges (Moeschler & Ruedi 1995). Preferred roosts are in old woodpecker holes, which become enlarged upwards by rotting within a living tree (European beech *Fagus sylvestris,* Common oak *Quercus robur,* European hornbeam *Carpinus betulus,* European ash *Fraxinus excelsior*) with a trunk diameter of at least 30 centimetres at 1 metre above the ground (Nagel & Häussler 2003, Dietz & Boye 2004). Fissures in stems, wood crevices, hollow branches, and bird or bat boxes are also used. Most roosts are found in or near the trunk of a broadleaf tree at a height of 1 to 25 metres above the ground (Meschede & Heller 2000, Rieger 1996). Roost trees are often situated near the forest edge: more than 40% are within 30 metres of the edge (Nagel & Häussler 2003). Most males roost alone, and in May and June they also use underground roost sites (Degn 1989, Kallasch & Lehnert 1995, Roer & Schober 2001).

Summer roosts are changed frequently. Females of a maternity colony switch among a network of several roost sites. The occupation of a roost may also change in composition between all males, all females or mixed groups (Dietz & Boye 2004).

Summer roosts of Daubenton's bat are sometimes shared with the noctule, Leisler's bat, greater mouse-eared bat *Myotis myotis*, Bechstein's bat, Brandt's bat, Natterer's bat *Myotis nattereri*, brown long-eared bat or Nathusius' pipistrelle *Pipistrellus nathusii* (Rieger 1996, Meschede & Heller 2000, Dobrosi n.y.).

Winter roosts: Winter roosts are nearly exclusively in caves, mines, cellars and other underground habitats, which have a very high humidity, temperatures above freezing, and no disturbance by humans (Dietz & Boye 2004). The best temperature of a hibernaculum is between 4 °C and 8 °C (Urbanczyk 1991). Large hibernation sites can host several thousands of Daubenton's bats (e.g. Segeberg Cave and Spandau Citadel in Germany).

Summer and winter roosts may be at a distance of up to 100 kilometres from one another (Roer & Schober 2001), but are more usually within 50 kilometres (Schober & Grimmberger 1998).

In most hibernation roosts there are also other bat species present, especially those of the genus *Myotis* and *Plecotus* (Dietz & Boye 2004).

Other roosts: In foraging areas and their wider surrounding other roost sites are visited which give cover for resting and from bad weather (Ruedi 1993) or have a social function (Haensel & Ittermann 1998).

Foraging areas: Foraging areas are predominantly at open water bodies and slow flowing rivers (Austria: Spitzenberger 2001, Denmark: Baagøe 2001a, Fennoscandia: Jensen 1993, Germany: Zahn & Maier 1997, Boye and others 1999, Kretschmer 2001, Greece: von Helversen & Weid 1990, Hanak and others 2001, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Moeschler & Ruedi 1995, The Netherlands: Limpens & Kapteyn 1991). Daubenton's bat prefers waters with trees or bushes on the banks so that not all the water surface is disturbed by winds (Spitzenberger 2001, Dietz & Boye 2004). The foraging success is also influenced by duckweed on the water (Boonman and others 1998). Sometimes, mainly in springtime, the bats also forage away from water, e.g. at a clearing in woodland. The use of particular foraging areas generally follows the abundance of Nematocera and Ephemeroptera (Dietz 1998, Kretschmer 2001). If prey abundance at the waters is reduced due to windy weather or cold nights Daubenton's bat forages instead in woodlands (Zahn & Krüger-Barvels 1996).

In oak forests individual home ranges were identified with an average size of about 49 hectares. Core areas within the home ranges are dependent on the size and structure of the water bodies and have sizes between 100 square metres and 7,500 square metres (Meschede & Heller 2000).

The results of investigations with telemetry and ringing show that Daubenton's bat is a mobile species which can cover distances between the roost and foraging areas of 7-8 kilometres without difficulty. On the way from the roost to a hunting ground the bats orientate along landscape structures, which mark the flight path (Ebenau 1995, Dietz & Fitzenräuter 1996, Klenk and others 1996, Rieger 1997, Kretschmer 2001).

Abundance: In a lake district in northern Bavaria (Germany) the summer abundance of Daubenton's bat was investigated by a capture-mark-recapture experiment on a 40 square kilometre plot. The result was an estimation of 30-40 individuals per square kilometre (von Helversen 1989).

3.4 Whiskered bat *Myotis mystacinus*

Forest habitats: The wide range of summer roost sites and foraging habitats includes a variety of forest types all over Europe.

Summer roosts: Summer roosts are in crevices and holes in buildings, in tree holes, and behind loose bark (Tupinier & Aellen 2001). In many cases the entrance to a roost is a very small opening (Nyholm 1965). Bird or bat boxes are used by single individuals or as mating roosts (Meschede & Heller 2000), only occasionally are boxes used by a maternity colony (Häussler 2003).

Brandt's bat and the greater mouse-eared bat have been observed in maternity colonies of whiskered bat (Tupinier & Aellen 2001, Boye 2004).

Winter roosts: Caves, mines and cellars with temperatures above freezing (0 °C–10 °C) and high humidity are used for hibernation (Tupinier & Aellen 2001).

The distance between summer and winter roosts is usually less than 50 kilometres. The furthest recorded is 240 kilometres (Tupinier & Aellen 2001).

In most underground hibernation sites other bat species are also present, especially of the genus *Myotis* and *Plecotus.*

Foraging areas: Whiskered bat forages in dense woodlands, park-like forests, along forest edges, banks, hedges and in gardens (Austria: Spitzenberger 2001, Germany: Taake 1984, 1992, Zahn & Maier 1997, Häussler 2003, Greece: Hanak and others 2001, Rottmann and others 2003, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Russia: Strelkov 1983, Spain and Portugal: Benzal and others 1991, The Netherlands: Limpens & Kapteyn 1991, Sweden: de Jong 1995). In Central Europe the bat prefers to forage in open habitats and in oak or oak and beech forests (Zingg & Burkhard 1995, Simon and others 2004). In south-eastern Europe the distribution finishes at the border of the deciduous forest zone and the steppe zone (Benda & Tsytsulina 2000).

The individual home range size is between 20 and 35 hectares (Nyholm 1965, Godmann 1995). Foraging activity is within a maximum distance of 1,250 metres from the roost site, but in most cases below 700 metres (Godmann 1995, Limpens and others 1997, Simon and others 2004).

Abundance: In the district of Marburg-Biedenkopf in central Germany the abundance of adult females was estimated to be at least 0.49 individuals per square kilometre (Simon and others 2004).

3.5 Brandt's bat *Myotis brandtii*

Forest habitats: Woodlands, especially old deciduous forests, are important habitats for roosting and foraging.

Summer roosts: Summer roosts are in buildings in wall crevices, in roof lofts, behind weather-boarding or in trees (Häussler 2003, Dense and others 2004). Strelkov (1983) stated that loose bark and large holes in tree trunks are the original roost sites of Brandt's bat, and for this reason Spitzenberger (2001) calls the species a characteristic element of woodland in its final decay phase. Tree holes and bat boxes are also used, especially by males during mating time (Dense and others 2004).

In summer roosts Brandt's bat is sometimes associated with other bat species: Daubenton's bat, whiskered bat, common pipistrelle, soprano pipistrelle and Nathusius' pipistrelle (Meschede & Heller 2000, Dense & Rahmel 2002, Ohlendorf and others 2002, Spagnesi and others 2000).

Winter roosts: Winter roosts are known only in underground sites like caves, mines and cellars (Meschede & Heller 2000). Specimens hang from the ceiling or on the wall or they hide in crevices and holes (Tupinier 2001).

Brandt's bat travels up to 250 kilometres between its summer and winter roost sites. The furthest recorded distance is 800 kilometres was recorded (Meschede & Heller 2000).

Foraging areas: Foraging areas are in woodlands, gardens and near waters or along hedges, tree rows, forest edges or ditches. Old growth deciduous forests with canopy cover and many structures in the undergrowth are preferred by the species (Austria: Spitzenberger 2001, Caucasus: Benda & Tsytsulina 2000, Abuladze and others 2001, Fennoscandia: Jensen 1993, Germany: Taake 1984, Zahn & Maier 1997, Häussler 2003, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Poland: Ruprecht 1974, Russia: Strelkov 1983, The Netherlands: Limpens & Kapteyn 1991, Sweden: Gerell 1987, Switzerland: Zingg & Arlettaz 1995). Specimens often fly for some time to and fro along a certain line (Dense and others 2004).

The home range of a maternity colony in northern Germany was estimated as 100 square kilometres (Dense & Rahmel 2002).

Regularly visited foraging areas may be at a distance of more than 10 kilometres from the roost site. Usually flights between roosts and foraging areas follow the shortest route along linear landscape structures such as hedges and tree rows (flight paths) (Dense & Rahmel 2002).

3.6 Natterer's bat *Myotis nattereri*

Forest habitats: Various woodland types are used as roost sites and foraging areas.

Summer roosts: During summer Natterer's bat chooses roost sites in woodlands and human settlements. Maternity colonies have been found in lofts, wall crevices, tree holes, wood crevices, and in forests also in bird and bat boxes (Meschede & Heller 2000). Many roosts of colonies are situated in cattle sheds (Trappmann & Clemen 2001, Meier 2002, Kockerbeck 2002, Simon and others 2004). Some colonies change their roosts frequently (Meschede & Heller 2000, Topál 2001). Siemers and others (1999) recorded 13 roosts used by a Natterer's bat colony in a 24.3 hectare area of forest. Laufens (1973) observed in an area with bat boxes a change of the roost site every one to four days in summer, and every 2-3 weeks in late spring and autumn. The colonies moved to roosts at a maximum distance of 2 kilometres from the first roost site.

A maternity colony in northern Germany was occasionally associated with Daubenton's bat (Dieterich 2002).

Winter roosts: Hibernation takes place in caves and mines that have high humidity and temperatures above freezing, sometimes even in buildings above the ground (Trappmann & Boye 2004). The animals often stay near the entrance of the hibernaculum (Ohlendorf 1989, Topál 2001). Natterer's bat prefers certain hibernation roosts (e.g. Segeberg cave, Spandau Citadel and Brunnen Meyer in Germany), where several thousand specimens accumulate during winter (Meschede & Heller 2000).

Summer and winter habitats may be separated by distances of up to 185 kilometres, but most are less than 80 kilometres apart (Schober & Grimmberger 1998, Meschede & Heller 2000, Topál 2001, Ohlendorf 2002a).

Other roosts: There seem to be special migration roosts where animals meet in early spring (March-April) and in autumn (October-November) (Ohlendorf 2002a).

Foraging areas: Foraging areas of Natterer's bat are in deciduous, mixed and coniferous forests, along forest edges, tree rows, hedges, and in pasture and arable land (Austria: Spitzenberger 2001, Georgia: Abuladze and others 2001, Germany: Trappmann 1996, Siemers & Schnitzler 1999, Kretzschmar 2003, Hungary: Dobrosi n.y., Greece: Hanak and others 2001, Italy: Spagnesi and others 2000, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, The Netherlands: Limpens & Kapteyn 1991, Limpens & Bongers 1991, Sweden: de Jong 1995, Switzerland: Ruedi and others 1995). In springtime most foraging activity is in open habitats such as orchards, fields and pastures with hedgerows and trees or near waters. However, in summer, foraging activity is concentrated in woodlands and the species even uses dense coniferous forests. Meier (2002) and Kockerbeck (2002) observed that females with roosts in forests also preferred to forage in the forest. Areas outside the forest were visited only on rare occasions. Other females, which raised their young in cattle sheds, foraged in open habitats to a greater extent and also hunted in the stables.

Natterer's bat prefers foraging areas at distances of 1,500 metres from the roost site, each with a size of two to 20 hectares (Trappmann & Clemen 2001, Meier 2002, Kockerbeck 2002, Kretzschmar 2003). Such core areas within a home range of 100-600 hectares, which are visited every night by the same individuals, were also identified by Siemers and others (1999) in south-western Germany. A speciality are foraging sites in cattle stables where the bats roost and feed on flies, so they do not have to leave the stable during summer (Trappmann & Clemen 2001, Simon and others 2004).

Foraging areas may be up to 3 kilometres from the roost site, but in late summer and autumn they are rarely more than 600 metres away from the roost (Meschede & Heller 2000, Kretzschmar 2003). In western Germany, males were observed to forage at distances of 350-1,000 metres from the roost, and females at 1-1,5 kilometres. As an exception maximum distances of 3.3 kilometres and even 4.8 kilometres were recorded (Trappmann & Clemen 2001, Meier 2002, Kockerbeck 2002).

On its way to the foraging areas Natterer's bat often uses flight paths along linear features like hedges and alleys (Meschede & Heller 2000). During the night the animals frequently change their foraging areas, which they share with other bats of the same species (Trappmann & Clemen 2001, Meier 2002, Kockerbeck 2002).

Abundance: In the district of Marburg-Biedenkopf in central Germany, Simon and others (2004) estimated the abundance to be 0.16 female Natterer's bats per square kilometre, however, they presumed 1 female per square kilometre was more realistic.

3.7 Bechstein's bat *Myotis bechsteinii*

Habitat forest types: Deciduous forests are the dominant habitats for roosting, foraging and probably hibernation also. As the species is only occasionally observed in other forest types or outside forests, Bechstein's bat is the most characteristic mid-European woodland bat.

Summer roosts: Most summer roosts are in woodpecker holes, sometimes behind loose bark or in tree crevices (Fuhrmann & Godmann 1994, Meschede & Heller 2000, Meinig and others 2004). Maternity colonies also use bat boxes (Kerth and others 2002). Roosts are found at a height of 0.5-18 metres (Meschede & Heller 2000).

In an investigation of populations using bat boxes it was observed that the animals of a maternity colony change their roost nearly every day. They visit the same roost site only 2-3 times per year. As a result the group of females in a certain roost is changing daily and the whole colony is spread across a large number of roosts, perhaps as many as 50 (Kerth 1998, Meschede & Heller 2000, Fuhrmann and others 2002). In regions without artificial roosts, however, telemetry has shown that maternity colonies stayed for a couple of weeks in a certain natural roost and females switched only rarely to other roosts (Meinig and others 2004.).

Maternity colonies are composed of closely related individuals (Kerth 1998). On the basis of genetic analyses Kerth and others (2000) estimated the exchange of females with a neighbouring colony to be one animal in five years. Males move to other regions and so ensure genetic mixing of populations (Baagøe 2001a).

Bechstein's bat was observed in summer roosts together with Daubenton's bat, Natterer's bat and Geoffroy's bat (Baagøe 2001a) as well as Leisler's bat (Schorcht 1998).

Winter roosts: In underground hibernation sites (caves, mines, cellars) Bechstein's bat is usually present singly. Most of the population may hibernate in tree holes or behind loose bark, but this is not proven (Meschede & Heller 2000).

The greatest distance between summer and winter roosts was 39 kilometres; usually the distances are much smaller (Baagøe 2001a).

Foraging areas: Bechstein's bat prefers deciduous forests with plenty of structure as foraging areas. However, there are also records from mixed and coniferous forests (Austria: Spitzenberger 2001, Czech Republic: Cerveny & Bürger 1989, Germany: Müller 2003, Meinig and others 2004, Greece: von Helversen & Weid 1990, Hanak and others 2001, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Zuchuat & Keller 1995, The Netherlands: Limpens & Kapteyn 1991). Another good habitat type is orchard with old trees. During summer the animals change foraging areas from time to time and visit both woodlands and open habitats (Meinig and others 2004).

The size of individual home ranges differs in relation to habitat quality: In optimal areas a home range might be smaller than 3 hectares (old oak forests or oak and beech forests), at other places its size is 15-30 hectares (Müller 2003). However, in coniferous forests home ranges of more than 100 hectares were recorded. Females of a maternity colony seem to use individual foraging areas exclusively for several years (Meschede & Heller 2000, Schlapp 1990, Wagner and others 1997, Wolz 1992). Home ranges of neighbouring colonies are separated (Lüttmann and others 2003).

The species shows a comparatively small range of movement around the summer roost, sometimes less than 1 kilometre (Wolz 1992, Friemel 1999, Albrecht and others 2002). The main foraging areas are usually at distances of 500-1,500 metres from the roost (Steinhauser 2002). However, the animals sometimes fly up to 3.8 kilometres. Foraging areas in continuous woodlands are smaller than those in fragmented forests (Kerth and others 2002, Lüttmann and others 2003).

3.8 Common pipistrelle *Pipistrellus pipistrellus*

Forest habitats: Although most maternity colonies are in buildings, forests of any type are used as roosting and foraging areas, particularly if open water is in the vicinity.

Summer roosts: The species mainly occurs in settlements and is even present in city centres. In summer the roost sites are predominantly in crevices in buildings (Dietz & Weber 2000), especially between tiles and the underlying roofing or behind boards on the gable (e.g. Rackow 1994). Furthermore, individuals and maternity colonies use tree holes, wood crevices, and bird or bat boxes as roosts (Eichstädt & Bassus 1995). Summer roosts are changed frequently, on the average every 11-12 days, so that colonies develop a roost site network with subgroups that change their composition each day (Feyerabend & Simon 2000).

The common pipistrelle can be associated with all other bat species that roost in buildings (Meinig & Boye 2004, Taake & Vierhaus 2004). Ohlendorf (1998) observed the species together with Nathusius' pipistrelle and Brandt's bat in bat boxes.

Winter roosts: The common pipistrelle hibernates in large caves or other underground rooms, but also in crevices in the outside walls of buildings (Meinig & Boye 2004, Simon and others 2004). The animals are usually not visible as they hide in narrow crevices where they have as much body contact as possible with the surrounding (Simon & Kugelschafter 1999).

In many regions of Germany and elsewhere there are mass hibernacula where many thousands of the common pipistrelle stay during winter (Dobrosi n.y., Decu and others 2003, Simon and others 2004, Uhrin 1995). At one of these German sites, for example, where mating is also recorded, genetic relatedness with the bats from the surrounding landscape with a radius of about 100 kilometres was proved (Hüttenbügel and others 1998).

Some individuals migrated across nearly 770 kilometres and successful homing was observed in specimens that were translocated more than 143 kilometres from their roost (Grimmberger & Borg 1979, Roer 1981, 1989). But usually the species is sedentary and the distance between summer and winter roosts is not more than 50 kilometres (Grimmberger & Bork 1979, Haensel 1979, Simon 1998).

Other roosts: After weaning of the young, the common pipistrelle visits temporary roost sites (Simon and others 2004). At this time the animals are swarming at hibernacula (Sendor & Simon 1998), probably to check the locality and its suitability for hibernation (Simon and others 2004).

Foraging areas: The common pipistrelle is abundant nearly everywhere in its range. Foraging areas are mainly along edge structures, e.g. forest edges, hedges, foot paths and forest roads, water banks, and at street lights (Austria: Spitzenberger 2001, Czech Republic: Vlasin & Malkova 1998, Denmark: Baagøe 2001a, Germany: Meinig & Boye 2004, Simon and others 2004, Greece: Hanak and others 2001, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Haffner & Stutz

1995, The Netherlands: Limpens and others 1997). Linear features in a landscape are important elements for orientation either during foraging or in commuting flights (Eichstädt & Bassus 1995, Verboom & Huitema 1997, Simon and others 2004).

Foraging activity is in small areas within about 2 kilometres from the roost. The size of an individual home range is dependent on the abundance of prey insects and may have a total size of more than 50 hectares (Eichstädt & Bassus 1995). Villages can host a maternity colony particularly if a large water body is at a distance of less than 600 metres (Simon and others 2004).

Abundance: In the district of Marburg Biederkopf in central Germany Simon and others (2004) made a careful investigation of the distribution of the common pipistrelle and estimated an abundance of 24-36 individuals per square kilometre. The estimated common pipistrelle population in The Netherlands is 300,000-600,000 animals (Limpens and others 1997), which gives an average abundance of 9-18 individuals per square kilometre. Estimates of 0.5 individuals per square kilometre in south-western Germany (Müller 1993) and 300 individuals per square kilometre in Romania (Gaisler 1979) seem to be inappropriate.

3.9 Soprano pipistrelle *Pipistrellus pygmaeus*

Forest habitats: In Scandinavia, forests are one summer habitat type among others, but in central and southern Europe competition with the common pipistrelle drives the soprano pipistrelle to live predominantly in wet deciduous forests and forests along rivers.

Summer roosts: The species is found in tree holes, behind loose bark, in bat boxes and in buildings (Häussler & Braun 2003, Vierhaus & Krapp 2004).

Winter roosts: In the flood forests of the upper Rhine Valley (Germany) the soprano pipistrelle seems to be present the whole year (Braun & Häussler 1999), but there are also some indications for distinct seasonal migration in other populations (Häussler and others 1999, von Helversen & Holderied 2003).

Other roosts: Soprano pipistrelle males show territorial advertisement in late summer and autumn. They occupy special mating roosts at this time (Lundberg & Gerell 1986, Lundberg 1990).

Foraging areas: The species prefers to forage around the canopy of broad-leaved trees (de Jong & Ahlén 1991). Thus, it does not occur in large, dense woodlands but forages along forest edges, river banks or in settlements. In the Mediterranean it can also be observed on the coast (Germany: Braun & Häussler 1999, Siemers & Nill 2000, Häussler & Braun 2003, Greece: Hanak and others 2001, Italy: Russo & Jones 2000, Sweden: de Jong 1995, Ekman & de Jong 1996).

3.10 Nathusius' pipistrelle *Pipistrellus nathusii*

Forest habitats: Woodlands are the most important habitats during summer, and forests along rivers seem to play an important role during migration and mating.

Summer roosts: Nathusius' pipistrelle prefers tree holes and wood crevices in deciduous and pine forests as summer roosts. Maternity colonies choose their roost sites mainly in woodlands or near the forest edge close to open water. Sometimes crevices in the wall of a house close to the forest are used as a roost. Single males also occur in other habitat types (Schmidt 1991, Meschede & Heller 2000, Vierhaus 2004). Besides natural hiding places the bats accept boxes as roosts. Small narrow bat boxes 4-5 metres above the ground with free access seem to be most appropriate for this species (Heise 1982, Meschede & Heller 2000).

In spite of long distance migration Nathusius' pipistrelle is very faithful to its place of origin. Females return to their home colony (Heise 1982, Schmidt 1984) and males also come back to their traditional mating areas and mating roosts each year (Meschede & Heller 2000, Boye & Meyer-Cords 2004).

Associations were recorded in roosts containing Brandt's bat, common pipistrelle, noctule and serotine *Eptesicus serotinus* (Meschede & Heller 2000, L. Ohlendorf and others 2002).

Winter roosts: Crevices in trees and buildings as well as in stapled wood are used as winter roosts (Vierhaus 2004). Holes and crevices in old forest and park trees are probably the most important hibernacula of Nathusius' pipistrelle groups, but there are only a couple of accidental observations of these roost types (Meschede & Heller 2000). In The Netherlands many hibernating bats were found in towns and other habitats near the coast (Grol & Lina 1982).

Females migrate from their maternity colony range to distant hibernation sites, thus flying several hundreds of kilometres twice each year. Males do not migrate that far and stay away from the region of maternity colonies in north-eastern Europe (Limpens & Schulte 2000, Vierhaus 2004). Migration obviously takes place along different routes in spring and autumn (Meschede & Helller 2000). The greatest flight distance ever recorded is 1905 kilometres from Latvia to southern France (Petersons 1990).

Other roosts: Mating roosts are of the same types as summer roosts but most are situated in flood forests of larger rivers, which may serve as guidelines for migration (Fiedler 1993, Boye & Meyer-Cords 2004, Arnold & Braun 2002).

Foraging areas: Foraging areas are over open water, along forest edges, over reeds or pastures, and sometimes in old-growth woodlands (Austria: Bauer & Wirth 1979, Spitzenberger 2001, Denmark: Baagøe 2001a, Fennoscandia: de Jong 1993, Germany: Dense 1991, Schmidt 1997, Arnold & Braun 2002, Schorcht and others 2002, Greece: Pieper 1978, von Helversen & Weid 1990, Hanak and others 2001, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Latvia: Petersons 1990, Luxembourg: Harbusch and others 2002, Poland: Ruprecht 1977, 1990, Jarzembowski and others 1998, Russia: Chistyakov 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Gebhard 1995, The Netherlands: Limpens & Kapteyn 1991). During distant flights from a roost to a foraging area the bats follow landscape structures, e.g. forest edges, hedges, roads or forest aisles, but they also go across open fields (Arnold & Braun 2002).

Nathusius' pipistrelle has a home range of 10-22 square kilometres in summer (Schorcht and others 2002). Certain foraging areas may be 6.5 kilometres from the roost site (Boye & Meyer-Cords 2004). The size of a foraging area is 18 hectares on average in eastern Germany (Eichstädt 1995). In northern Germany, four individual home ranges of females from a maternity colony covered a total area of 5.8 square kilometres (Schorcht and others 2002). The home range of an entire colony is approximately 80 square kilometres (Meschede & Heller 2000, Arnold & Braun 2002).

Abundance: In optimal mating areas 2.3-7.6 males can establish their territories per square kilometer (Schmidt 1994a).

3.11 Serotine *Eptesicus serotinus*

Forest habitats: Woodlands are of minor importance to serotines. They may forage on forest edges, but rarely hunt in a forest or roost in a tree.

Summer roosts: Preferred roost types are crevices and other narrow holes in houses (Rosenau & Boye 2004). Until now maternity colonies have only been recorded in buildings (e.g. Hübner 1991, Dense 1992, Schmidt 1998, Rosenau 2001, Harbusch 2003). The bats roost below the ridge of a roof (e.g. Schmidt 1998), behind fascia boards (e.g. Rosenau 2001), in ventilation holes of new blocks (Bauerova & Gaisler 1985), or in the extension slits of bridges (Pérez & Ibáñez 1991). Single animals, males in most cases, sometimes use a tree hole or a bat box as their roost (Rosenau & Boye 2004). The serotine changes its roost site or hanging place if the microclimate in the roost becomes uncomfortable, e.g. if temperatures rise too much (Labee & Voute 1983, Hübner 1991, Schmidt 1998, Rosenau 2001).

Maternity colonies have different strategies of roost site utilization: There are records of a single roost site used for the whole maternity period (Glas 1981, Hübner 1991), of a main roost and a couple of near-by satellite roosts (Dense 1992), and frequent changes within a roost site network (e.g. Schmidt 1998, Dietz & Simon 1999, Rosenau 2001, Simon and others 2004).

In its summer roosts the serotine can be associated with the greater mouse-eared, Brandt's bat, the common pipistrelle and the brown-long eared bat (Taake & Vierhaus 1984, Braun 2003, own observation), while other small species like the whiskered bat may be pushed away (Franke 1997).

Winter roosts: Winter roosts are in cellars, mines and caves (Heidecke 1987, Haensel 1989, 1992), in old buildings and crevices in walls (Hildenhagen & Taake 1982). Single specimens occasionally hibernate in their summer roost (Lubeley 1998). No records of hibernating serotine bats are of more than three individuals (Baagøe 2001b).

Summer and winter roosts are thought to be less than 50 kilometres apart, however little is known (Rosenau & Boye 2004).

Foraging areas: In most cases the foraging areas are open fields with some woods on the edge. In agricultural landscapes the bats prefer pasture with tree rows for protection from winds (Verboom & Huitema 1997, Schmidt 2000, Lubeley & Bohle 2001). In addition forest edges, river banks, parks, tree rows, back yards, sports grounds, and garbage depots are appropriate foraging areas (Austria: Spitzenberger 2001, Denmark: Baagøe & Jensen 1973, Baagøe 2001a, Germany: Rosenau 2001, Braun 2003, Greece: Hanak and others 2001, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Stutz & Burghard 1995, The Netherlands: Limpens & Kapteyn

1991). Within settlements the species also hunts along the rows of streetlights (Baagøe 1986, Rydell 1992). Occasionally the serotine forages in woodlands (Meschede & Heller 2000, Harbusch 2003).

Harbusch (2003) estimated individual home ranges of females from a maternity colony in western Germany to have an average size of 4.6 square kilometres. During 90% of their activity the bats were less than 1.7 kilometres away from their roost. In Spain, Perez & Ibanez (1991) observed individual home range sizes between 0.16 and 47.6 square kilometres. Following the results of telemetry studies the colonial home range of maternity colonies is in Germany about 9.4 square kilometres in towns (Berlin: Rosenau 2001) and between 13 and 26 square kilometres in rural areas (Hesse: Diehl 1994 and Saarland: Harbusch 2003). In Denmark it has a size of about 2 square kilometres (Degn 1983).

Each individual visits 2-8 different foraging areas per night. In maternity colonies the foraging areas are at an average distance of 1.25 kilometres from the roost, and a maximum of 5.7 kilometres (Hesse: Simon and others 2004) or 4.5 kilometres (Saarland: Harbusch 2003). In towns the serotine rarely forages further than 1 kilometre from the roost (Berlin: Rosenau 2001).

Abundance: In the district of Marburg-Biedenkopf in central Germany Simon and others (2004) estimated the abundance to be at least 0.86 individuals per square kilometre.

3.12 Noctule *Nyctalus noctula*

Forest habitats: The noctule is a typical forest species that forages, breeds, mates, and hibernates in woodlands.

Summer roosts: Noctule summer roosts are predominantly in woodlands and parks. Deciduous and flood forests with a high percentage of old and dead trees are of highest importance. Roosts are mostly in woodpecker holes in broad-leaved trees (Stratmann 1978, Heise 1985, Kronwitter 1988, Frank 1997, Boonman 2000). In a woodland hosting noctules year round, the bats used more than 60 trees for roosting. Over the years they used nearly 25% of all available tree holes in the area (Frank 1997). Maternity colonies use several roost sites in a network, which means that the individuals often change from one roost to another (Stratmann 1978, Heise 1989). Associations of males, which change their roost site on average every second or third day, need at least eight tree holes suitable for roosting per square kilometre of forest. Besides tree holes the bats also roost in bat boxes (flat constructions are preferred, Heise & Blohm 1998) and small spaces behind wall coverings of buildings (Zahn and others 2000) or in houses (e.g. Meise 1951).

In its summer roosts the noctule sometimes occurs together with Leisler's bat, Daubenton's bat, Nathusius' pipistrelle, soprano pipistrelle or other bat species (Schmidt 1988, Häussler & Nagel 2003, Gebhard & Bogdanowicz 2004). Single specimens were even recorded in maternity colonies of the greater mouse-eared bat (Zahn 1999).

Winter roosts: Winter roosts are mainly in forest and park trees (Boye & Dietz 2004), but large hibernation colonies also roost in buildings or rock crevices (e.g. Perrin 1988). Tree holes must provide a lot of space for a large number of bats to be a good hibernaculum of the species (Sluiter and others 1973, Trappmann & Röpling 1996). The largest known hibernaculum is the Levensau Bridge in northern Germany where about 5,000 specimens come together in early winter (Harrje 1994, Kugelschafter 1994).

In their winter roosts the noctule was observed together with Leisler's bat and the common pipistrelle (Boye and others 1999, Gebhard & Bogdanowicz 2004).

During migration it is possible that very large numbers of bats occur at places where few animals live during summer. This happens mainly in valleys of large rivers and in lake districts, which obviously have an important function during the seasons due to a lot of prey insects there (Meschede & Heller 2000, Weid 2002).

Summer and winter roosts can be very distant from one another; more than 1,000 kilometres is not unusual. Specimens living in north-eastern Germany during summer are regularly found in south-western Germany or Switzerland during winter (Boye and others 1999). In other European regions the preferred direction of migrations is not yet known. The greatest migration distance is about 1,600 kilometres (Boye & Dietz 2004).

Other roosts: In late summer and autumn males occupy special mating roosts where they behave territorially and advertise with specific mating calls (Gloza and others 2001). In mating areas such roosts have to be close to each other, so that passing females are attracted and interrupt their migration (Meschede & Heller 2000).

Foraging areas: Foraging areas may be in several parts of the landscape, all of which host a high abundance of insect fauna and offer the space in the air needed by the fast flying noctule. Large water bodies, valley pastures and open forests are preferred, but the bats also forage in other habitats, and even above harvested fields and lighted places in towns (Austria: Spitzenberger 2001, Czech Republic: Gaisler and others 1979, Denmark: Baagøe 2001a, Germany: Meschede & Heller 2000, Greece: Hanak and others 2001, Rottmann and others 2003, Hungary: Dobrosi n.y., Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Rachwald 1992, Spain and Portugal: Benzal and others 1991, Switzerland: Stutz & Haffner 1989, Gebhard & Zingg 1995, The Netherlands: Limpens & Kapteyn 1991). The noctule visits each individual foraging area each night in the same sequence (Kronwitter 1988).

Noctule bats can easily make foraging flights more than 10 kilometres away from the roost site (Meschede & Heller 2000), up to a maximum of 20 kilometres (Limpens and others 1997, Heise 1999). However, the main activity of a maternity colony is within a radius of about 2 kilometres from the colony's roost (Schmidt 1988).

3.13 Leisler's bat *Nyctalus leisleri*

Forest habitats: Leisler's bat or the lesser noctule is also a typical woodland species, as it occurs in many forest types and mostly roosts in trees.

Summer roosts: Summer roosts are in tree holes, tree crevices, bird or bat boxes and more rarely in buildings or between timbers (Shiel & Fairley 2000, Braun & Häussler 2003, Bogdanowicz & Ruprecht 2004). Roosts in trees can be found from about 1.5 metres above the ground up to the canopy (Ruczynski & Ruczynska 2000). In some regions woodpecker holes in side branches are preferred, if the bats can approach them from below (Günther and others 1991, Ruczynski & Ruczynska 2000). Three individuals studied by radiotelemetry in

Germany changed roosts nearly every day. All of the roosts were in woodlands at distances of 50-1,700 metres from each other (Fuhrmann and others 2002).

In eastern Germany a maternity colony of about 40 females used a roost site network of 50 roosts during one year of investigation. The bats moved within this network frequently (Meschede & Heller 2000, Schorcht 1998).

Leisler's bat has been recorded to share summer roosts with Daubenton's bat, Bechstein's bat, common pipistrelle, Nathusius' pipistrelle and noctule (Meschede & Heller 2000).

Winter roosts: Hibernating animals were found in Switzerland in tree holes, in Germany there are observations from bat boxes (Meschede & Heller 2000, Bogdanowicz & Ruprecht 2004).

Leisler's bat is considered a long distance migrant. Winter roosts of a population resident in Germany during summer are at least partly at a very large distance (400-1,100 kilometres, e.g. Spain). Through ringing experiments, seasonal migrations were proved between Russia and the Turkish Black Sea coast, Poland and Slovakia and between Germany and Spain, France, Austria and Switzerland (Roer 1989, Ohlendorf and others 2001, Schorcht & Boye 2004).

Other roosts: Besides the roosts used during the day females have special roosts for rests or social contact, where they sometimes stay for several hours at night together with conspecific females from other colonies. They leave these roosts before dawn, returning to their day roosts (Fuhrmann and others 2002, Schorcht 2002). During mating time males occupy special mating roosts, which are situated ideally on top of a hill and have free flight access. The territorial males patrol within a radius of about 300 metres around the mating roost and start swarming if they can attract a female (Ohlendorf & Ohlendorf 1998).

Foraging areas: There is little information about foraging areas in the various parts of the distribution area in Europe (Bogdanowicz & Ruprecht 2004, Miric & Paunovic 1997, Austria: Spitzenberger 2001, Greece: von Helversen & Weid 1990, Hanak and others 2001, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Russia: Grigoryev & Vassilyev 1999, Slovenia: Krystufek 1974, Spain and Portugal: Benzal and others 1991, Switzerland: Stutz & Zingg 1995, The Netherlands: Limpens & Kapteyn 1991). Following observations made in Germany, it seems the bats choose their foraging areas because of prey abundance and free flight space, not because of habitat structures (Meschede & Heller 2000). In eastern Germany a telemetric study found that Leisler's bat forages on the one hand in large woodland areas, having no preference for certain forest types or stands, and on the other hand in diverse open landscapes and over water. They did not avoid human settlements (Schorcht 2002). In southwest Germany most foraging activity is recorded at lakes and rivers near forests, above forest clearings and along forest roads or rides. Each foraging area is used only for limited time of the year (Harbusch and others 2002).

In Germany home ranges were estimated to be at least 1.5 square kilometres in size for an advertising male and 6 square kilometres for a female. The foraging areas visited during the investigation were all in forests in the case of the male, but for about 50% of time were outside the forest at a river valley, in orchards and along street-lit roads in the case of the female (Fuhrmann and others 2002). In springtime and during the time of rearing the young, home ranges are often significantly larger than in late summer.

During their foraging flights Leisler's bat travels over 17 kilometres away from its roost site. Females from maternity colonies regularly go to areas 5 kilometres away from the colony's roost (Schorcht 2002).

3.14 Brown long-eared bat *Plecotus auritus*

Forest habitats: The brown long-eared bat occurs in a variety of habitat types but it prefers deciduous forests and avoids areas without woodlands.

Summer roosts: Summer roosts are usually in tree holes, but the species also uses wood crevices, loose bark, and quite often bird or bat boxes (Meschede & Heller 2000). The brown long-eared bat is also regularly seen in lofts of churches or smaller buildings near forests (Hanák 1969, Beck and others 1995, Horácek & Dulic 2004). Fuhrmann & Godmann (1994) recorded roosts in trees from the canopy down to the lower trunk. The entrance of a roost may be hidden behind branches or vegetation (Fuhrmann & Seitz 1992, Leitl 1995).

Females from maternity colonies in tree holes or bat boxes change their roosts every second to fourth day (Heise & Schmidt 1988, Fuhrmann 1991, Fuhrmann & Seitz 1992), but maternity colonies in lofts usually stay in the building the whole summer (Horácek 1975, Kiefer & Boye 2004).

In summer roosts the species has been recorded together with Daubenton's bat, the serotine and the grey long-eared bat.

Winter roosts: Winter roosts are in caves, mines and cellars, where the animals prefer a temperature around 7 °C (Kiefer & Boye 2004). There are a few observations of hibernation in tree holes, but it cannot be excluded that those having walls of wood more than 10 cm thick are regularly used as frost-free hibernacula (Meschede & Heller 2000).

The brown long-eared bat is a less migratory species than some other bats. The summer and winter roosts are rarely separated by more than 20 kilometres. Long distance migration in the species is only exceptionally more than 50 kilometres (Horácek 1975, Hurka 1989).

Foraging areas: Deciduous forests with different ages of trees are preferred as foraging habitats, but less structured woodlands (including coniferous forests), forest edges, bushes and hedges, orchards, parks and gardens are used for insect hunting (Austria: Spitzenberger 2001, Fennoscandia: Jensen 1993, Germany: Kulzer 1989, Fuhrmann & Seitz 1992, Kiefer & Boye 2004, Greece: von Helversen & Weid 1990, Hanak and others 2001, Italy: Spagnesi and others 2000, Luxembourg: Harbusch and others 2002, Poland: Kowalski & Ruprecht 1981, Woloszyn 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Beck and others 1995, The Netherlands: Limpens and others 1997).

The home range of an animal is related to habitat structures and prey abundance and has a size of between one and 40 hectares. Individual foraging areas overlap to a minor extent (Fuhrmann & Seitz 1992, Meschede & Heller 2000) and even maternity colonies seem to have territories (Heise & Schmidt 1988, van Riesen & Dolch 2003). Dolch (1995) estimates the home range of a maternity colony during rearing of the young to be one square kilometre, and during the phase of the colony's dissolution to be at least 10 square kilometres. After that phase the bats disperse to different hibernation sites in an area of about 100 to 400 square kilometres maximum (Dolch 1995).

During foraging flights the brown long-eared bat usually stays close to the roost, travelling a maximum distance of about 3 kilometres (Fuhrmann & Seitz 1992). Most of the activity time is spent in certain parts of the home range, which are core areas. Each core area has a size of 0.75-1.5 hectares and is less than 1,500 metres from the roost (Fuhrmann 1991, Fuhrmann & Seitz 1992, Eichstädt 1995, Arnold 1999).

Abundance: In northeast Germany the density of brown long-eared bat in mixed woodland was estimated to be at least 20-35 individuals per square kilometre (Heise & Schmidt 1988).

3.15 Grey long-eared bat *Plecotus austriacus*

Forest habitats: The grey long-eared bat prefers warm and dry habitats and is therefore characteristic of open habitats. Forests are populated only in the Mediterranean.

Summer roosts: In Central Europe summer roosts are in most cases (always in the case of maternity colonies) in buildings. Lofts, holes in walls and crevices behind wall coverings are preferred roost sites. Compared to the brown long-eared bat this species is more often found in lofts of large roofs (Horácek 1975, Kiefer 1996, Beck 1995), where selection of different hanging places is possible in relation to changes in seasonal temperatures (Kiefer & Veith 1998b). In eastern European steppe and semi-desert zones summer roosts are in caves, wells and loam-wall houses (Strelkov 1988). Single males also use caves and mines as summer roosts (May-August) in Central Europe (Spitzenberger 2001).

The grey long-eared bat is a very colony-faithful species. Females return to their home maternity colony. Movement of a female to a neighbouring colony has never been recorded (Kiefer 1996).

Summer roosts are shared with the brown long-eared bat, lesser horseshoe bat, greater mouse-eared bat, Natterer's bat, whiskered bat and the common pipistrelle (Braun & Häussler 2003).

Winter roosts: Specimens move to rock crevices, cellars or wall crevices for hibernation. Sometimes they hang in a church or on the outside wall of a building or they sit in house martins' nests (Berg 1989, Podany 1995, Kiefer & Boye 2004, Horácek and others 2004). Crevices of church towers made from natural rocks seem to be typical hibernacula where the bats can cope with air temperatures of –7 °C (Kiefer 1996, Kiefer & Veith 1998b). Sometimes individuals change their hibernation place during winter, but never the winter roost site.

The grey long-eared bat has been recorded migrating up to 18 kilometres between summer and winter roosts (Kiefer & Veith 1998a). The longest recorded movement of more than 62 kilometres (Hurka 1989) seems to be an exception.

Other roosts: In late summer interval roost sites are used, which are occupied during the day or only for some hours during dusk and night (Berg 1989).

Foraging areas: In Central Europe foraging areas of the species cover arable land, pasture, uncultivated fields, gardens, orchards, and forest edges. Less frequently the bats forage in towns, barns or other buildings (Austria: Spitzenberger 2001, Czech Republic: Gaisler & Bauerova 1986, Germany: Castor and others 1993, Flückinger & Beck 1995, Braun & Häussler 2003, Greece: Hanak and others 2001, Luxembourg: Harbusch and others 2002, The Netherlands: Limpens and others 1997). Through telemetry the species was also recorded in woodlands, where deciduous forests (especially old beech forests) were preferred (Kiefer 1996, Kiefer & Veith 1998a, Simon and others 2004). In southern Europe foraging areas are in valleys, on mountain slopes with dry bush vegetation, in steppe areas and in villages (Horacek and others 2004, Greece: Rottmann and others 2003, Italy: Spagnesi and others 2000, Spain and Portugal: Benzal and others 1991).

Foraging areas are at maximum of about 5.5 kilometres distant from the roost. Some closer foraging areas (less than 1.4 kilometres distant) are visited several times per night (Flückinger & Beck 1995, Kiefer 1996, Arnold 1999).

3.16 Barbastelle *Barbastella barbastellus*

Forest habitats: Woodland is the main habitat used by the barbastelle. Because of its preference for roosting behind loose tree bark and changing roost frequently, the barbastelle mainly occurs in old growth woodlands with many ancient and dead trees.

Summer roosts: Most summer roosts are found in narrow crevices in trees or buildings, but the preferred natural roost sites seem to be behind loose bark. Sometimes woodpecker holes are used and the species is frequently found behind window shutters or wall cover (shingles from wood or slate) on houses (Nagel 2003, Boye & Meinig 2004, Schober 2004). On rare occasions the species is observed in bat boxes (Bachmann & Pröhl 1990, Spitzenberger 1993). During spring and summer roost sites are changed frequently, sometimes every day, so that the group composition varies continuously (Steinhauser 2002).

In summer roosts the barbastelle may occur in association with Brandt's bat, whiskered bat, Natterer's bat and the brown long-eared bat (Meschede & Heller 2000, Weidner 2000).

Winter roosts: Winter roosts are known in karst caves, old mines and bunkers. Most of the population probably hibernates in tree crevices and walls of houses (Podany 1995). Some particular winter roosts are preferred as hibernacula, where many animals from the region accumulate (Richarz 1989, Uhrin 1995, Urbanczyk 1991, Gazaryan 2000). The best conditions in an underground hibernaculum are a temperature of 1.6-4.8 °C and humidity of 70-90 % (Urbanczyk 1991).

Regular migration across large distances is not proved. Summer and winter roosts seem to be a maximum of 20 kilometres apart (Dolch and others 1997). However, through ringing some long distance flights, up to 290 kilometres, were recorded (Spitzenberger 1993).

Other roosts: Interval (temporary) roost sites are visited during migration time in spring and autumn. Those used in autumn can serve as mating roosts as well (Schober 2004, Bachmann & Pröhl 1990, Spitzenberger 1993).

Foraging areas: Foraging areas are predominantly in woodlands or parks, but they can also stretch along forest edges, tree rows, hedges, waterways, or field roads with trees (Meschede

& Heller 2000, Austria: Spitzenberger 2001, Denmark: Baagøe 2001a, Greece: Hanak and others 2001, Spain and Portugal: Benzal and others 1991, Switzerland: Reymond & Arlettaz 1995, Sierro 1999, The Netherlands: Limpens & Kapteyn 1991). In Germany no preference for certain forest types was identified (Steinhauser 2002). In south-western Germany the species was also observed foraging above water in a similar style to Daubenton's bat (Nagel 2003).

The home range extends up to 8-10 kilometres around the roost (Poszig and others 2000, Boye & Meinig 2004, Simon and others 2004) and can be crossed several times per night by each individual. In many cases the radius of the home range is less than 500 metres, and in adult males may be as little as 100 meters only (Steinhauser 2002). Foraging takes place in two or more core areas within the home range, which have a size of 2-70 hectares each (Poszig and others 2000, Steinhauser 2002, Simon and others 2004).

4. What parts of woodland are important to bats?

Woodland has to offer the resources bats need due to their biology. The importance to bats of woodland or a part of it may be characterized by a prominent function of the woodland either as roost site or foraging area or both. It may also play a special role in the life of bats during a certain season, because of special requisites like open water, or because of its geographic location. The more resources available for bats in a woodland during the different seasons of a year, the more important that woodland or a part of it is to bats.

In a document of the EUROBATS Agreement the resources in woodlands that are most important to bats were called key elements and key areas. In the next two chapters these terms will be discussed and clarified with reference to roosting and foraging behaviour of bats. However, key elements and key areas are scientific ideas to describe and classify a landscape populated by bats. Their importance is always related to the size and structure of the woodland, the landscape surrounding the woodland, and the bat species in consideration.

4.1 Natural roosts in woodlands

Tree holes are regularly used as roosting places for most bat species occurring in Great Britain. Depending on the species, tree holes are used for rearing young (nursery or maternity colonies), as mating roosts or as temporary/interval roosts during nightly foraging flights or during migration. Some species even spend the winter in hollow trees (Table 2). All tree holes used as bat roosts can be considered key elements for woodland bats.

4.1.1 Maternity roosts

In late spring (approximately from the second half of May) reproductive female bats form maternity colonies, which are stable social units. Depending on the species, females can group themselves into colonies of between ten and more than 100 bats in one roost. The birth phase lasts from May until mid-June depending on the outside temperature. A 4-6 week suckling phase follows until the young become volant. The nursery colonies dissolve at the end of July or beginning of August. Nursery colonies are very faithful to their location and they visit the same woodland areas each year and within these areas the same roosts. During the whole phase of maternity, many bats regularly change roosts within an area.

Table 2 Importance of tree holes for bat species occurring in Great Britain (● = regularly used, ○ = occasionally used, ? = unknown but probable use)

Species	Function			
	Nursery	Males/Migration	Mating	Winter
Rhinolophus ferrumequinum		○		
Rhinolophus hipposideros		○		
Myotis daubentonii	●	●	●	
Myotis bechsteinii	●	●	●	○
Myotis nattereri	●	●	?	○
Myotis mystacinus	○	○	?	
Myotis brandtii	●	●	?	
Pipistrellus pipistrellus		●	○	○
Pipistrellus pygmaeus		○	?	
Pipistrellus nathusii	●	●	●	●
Eptesicus serotinus		○		
Nyctalus noctula	●	●	●	●
Nyctalus leisleri	●	●	●	●
Plecotus auritus	●	●	?	
Plecotus austriacus		○		
Barbastella barbastellus	●	●	?	○

4.1.2 Male roosts

Male bats live solitarily or in groups at various distances from the female colonies during the time of maternity, depending on the species. Tree holes are very often used by males, sometimes up to 80 males share a roost, e.g. in Daubenton's bat (Encarnação and others in prep).

4.1.3 Mating roosts

Many bats use tree holes as mating roosts between August and October. This is best known in the noctule and Nathusius' pipistrelle. Males emit mating calls at the entrance of the tree hole or during display flights outside it. Mating roosts are used annually with high fidelity comparable to maternity roosts.

4.1.4 Interval roosts/migration roosts

Tree holes are very often used for a rest during nightly foraging. These interval or temporary roosts are known for nearly all bat species. However, the term really refers to the time before entering the hibernation roost or to the time after leaving it and before reaching the summer habitats. These seasons of the year are characterised by unpredictable weather conditions. Relatively small groups of bats can survive bad weather periods by spending longer periods of torpor in interval roosts. If the temperatures are warm enough, they emerge and forage.

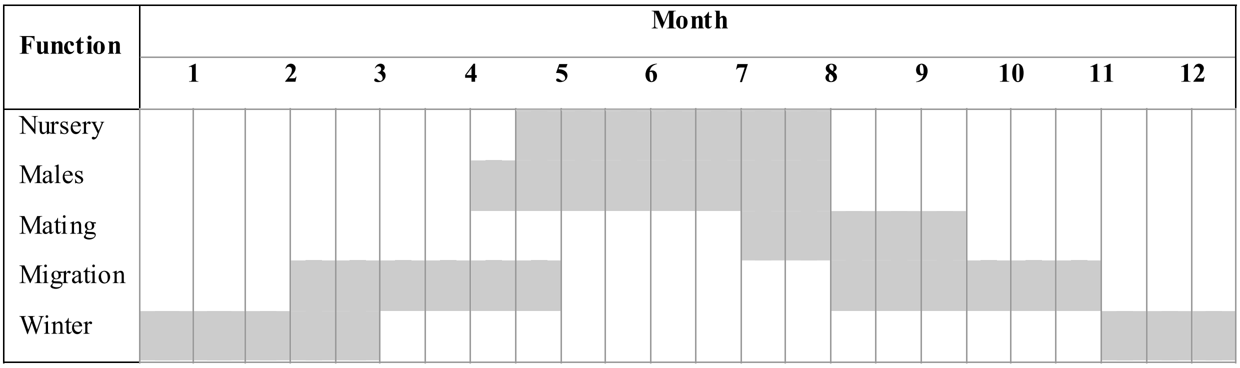
Presumably quite special interval roosts are the so-called migration roosts. These are preferred by young bats, which form juvenile groups after leaving the maternity roost sites at the end of the summer. Besides food acquisition, it is very important for them to gain sufficient knowledge about available roosts. For a very mobile bat species like the noctule this reconnaissance phase is confined to the immediate area during the first few days of flight ability. After a few weeks, marked young bats have been shown to have already travelled

100 to more than 1,000 kilometres from the place of birth. It is remarkable that during these migrations they use those woodlands and tree holes that are occupied annually in these seasons by migrating bats. Such tree holes are often used also for hibernation in winter.

4.1.5 Hibernation roosts

Hollow trees are important for some bat species as hibernacula. They lie in climatically favourable lowlands predominantly in woodland areas but also in parks. Those hollow trees are approached by the bats with the first frost, which, in Central Europe, is usually in mid-November. Bats sometimes form large groups in hibernation roosts, e.g. the noctule where a colony may contain more than 900 individuals (Frank & Dietz 1999). Several hibernation roosts are in trees standing close to each other (Frank 1997). They are consistently used over many winters (Bock 2001). The hibernation colonies start to disperse from the end of February until the middle of March.

Table 3 Function of tree holes for bats in the course of the year



4.2 Which roost types are important?

Due to their insectivorous dentition, bats are not able to make suitable roosts themselves. Rather, they depend on natural tree holes or those made by other animals. Different types include woodpecker holes, crevices, rotted knotholes and loose bark (cf. Meschede & Heller 2000).

Species have different requirements from a tree hole and these might change throughout the year depending on the function of the roost (Tables 3 & 4). In general bats seek protection from the weather and predators in their roost. Furthermore a tree hole should enable bats to stay away from their droppings. An ideal tree hole has a hanging place above the entrance and a hollow below into which droppings can fall. Woodpecker holes with the former nest site below the entrance hole fulfil this criterion if they have been enlarged upwards by the influence of fungi and rotting over time (van Heerdt & Sluiter 1965, Stratmann 1978). Similar development processes are observed in other roost types that have arisen by bark damage or branch loss.

The volume of a tree hole is another criterion of its quality. Maternity roost sites must offer at least enough room that a group of females with their young can be resident. This is even more important for hibernation roosts, e.g. for the noctule or other tree hibernating species. A roost of noctules in the Philosophenwald in Giessen (Hesse, Germany) with up to 900 hibernating animals had a volume of 53 litres. In an examination of twelve hibernation roost sites it was found that the possibility of forming large groups was of greater importance than the thickness of the tree (Dietz & Frank personal observation).

When reviewing the literature about tree-dwelling bat species it becomes clear that woodpecker holes play an important role for almost all bat species. These are primarily the holes of the great spotted woodpecker, middle spotted woodpecker, grey-headed, and green woodpecker (*Picoides* and *Picus* species). Holes of the black woodpecker are not often occupied, possibly because of the big entrance and the danger of predation by martens.

Crevices in the trunk or in strong side branches are also very frequently used, if they provide enough hollow room and hiding places above the entrance. Which of these two roost types is preferred can be different in one species, depending on the area (cf. Daubenton's bat: Nyholm 1965, Geiger 1992, Dietz 1993, Rieger 1996). Initially it is presumably dependent on the availability of structures in a region but the imprinting phase of the young could also play an important role for habitat preference and roost selection, a feature typical of mammals.

Roosting under loose bark is characteristic of the barbastelle (Steinhauser 2002, personal observations), and sometimes also for Brandt's or whiskered bats and Nathusius' pipistrelles.

Table 4 Tree hole types used by bats

Species	**Roost type**			
	woodpecker hole	**crevices**	**bough damage**	**Behind loose bark**
Rhinolophus ferrumequinum				
Rhinolophus hipposideros				
Myotis daubentonii	●	●	○	
Myotis bechsteinii	●	○		○
Myotis nattereri	●	●		
Myotis mystacinus		○		●
Myotis brandtii		●		●
Pipistrellus pipistrellus		○		○
Pipistrellus pygmaeus		?		?
Pipistrellus nathusii	●	●	○	●
Eptesicus serotinus		○		○
Nyctalus noctula	●	●	○	
Nyctalus leisleri	●	●	○	○
Plecotus auritus	●	●		
Plecotus austriacus				
Barbastella barbastellus		○		●

[personal observation on Bechstein's bat, Daubenton's bat, Natterer's bat, whiskered bat, Brandt's bat, noctule, Leisler's bat, brown long-eared bat and barbastelle; furthermore: Bechstein's bat (Bayerl 2004), Daubenton's bat (Rieger 1996), Natterer's bat (Siemers and others 1999), whiskered bat (Taake 1984, Godman 1995), Brandt's bat (Dense & Rahmel 2002), common pipistrelle (Taake & Vierhaus 2004), Nathusius' pipistrelle (Schorcht and others 2002, Vierhaus 2004), noctule (Gaisler 1979, Frank 1997), Leisler's bat (Schorcht 2002), brown long-eared bat (Fuhrmann & Seitz 1992) and barbastelle (Steinhauser 2002)]

Figure 1 Examples of tree holes (clockwise from top left: Brown long-eared bat looking from a woodpecker hole; woodpecker hole; loose bark; crevices). Photos T Stephan/M Dietz

4.3 Microclimate

The microclimatic conditions of bat roosts in trees are still largely unexplored. Kerth, Weissmann & König (2001) indicate that female Bechstein's bats prefer warmer roosts during the suckling phase than during pregnancy and postlactation. However, their measurements are exclusively based on examinations at artificial roosts. A change from a warm roost in a building, primarily used during the embryonic development phase, to cooler tree roosts later in the year was observed for Brandt's bat by Dense & Rahmel (2002). In our own experience there were no detectable temperature differences in maternity roost sites of the Daubenton's bat in hollow trees. However, Daubenton's bat roosts appear to be damper than those of other bat species. Tree holes do not protect against freezing during persistent frost periods in winter. The volume of the hole and the possibility to form large colonies presumably increases the survival rate under these conditions (Frank & Dietz 1999).

4.4 Tree species, vitality and thickness

Deciduous trees, primarily oak and beech, dominate among trees occupied by bats. Roosts in conifers are much more rare and, if occupied, are generally dry spruces, which are hardly resiniferous, or pines in which the bark comes loose in large pieces. In deciduous trees the roosts are frequently in dying and dead trees as well as in living trees. In the former, roosts can be woodpecker holes, but are mainly behind loose bark (oak, ash, elm), or in trunk crevices arisen from frost cracks or lightning strikes.

Bats mainly occupy roosts in trees with at least 20 centimetre diameter at breast height. Trees below this diameter are seldom used for maternity roost sites. Since with the advancing age of a tree its potential for holes increases, most tree holes are found in trunks with more than 40 centimetres diameter at breast height. Age and degree of decomposition influence the conditions for hole development. In good conditions, the ability of woodpeckers to create holes in trees starts at approximately 80 years of tree age (Blume 1990) and trees offer a sufficiently large diameter for spacious holes at this age. In less optimal conditions it starts later. Conditions for rotting to start and for the construction of breeding and roosting holes by woodpeckers improve with tree age. Scott (1978), Schuster (1985) and Zahner (1993) correspondingly stated a higher density of holes with the advancing age of the trees.

Bat roosts can be found from the root butt up to the canopy, the lowest height depends on the flight ability of the bat species. Noctules do not occupy any roosts less than 2 metres above the ground while entrances to roosts of brown long-eared bats or Natterer's bats can be as little as 30 centimetres above the ground. Usually though, bat roosts are between 3 and 15 metres from the ground.

4.5 Location of tree roosts

Bat roosts can be in the centre of woodland as well as in the edge areas. Whether there are species differences has not yet been proved. In a radio-tracking study on the Nathusius' pipistrelle, Schorcht and others (2002) stated that roosts tended to be found primarily in sunny edge areas near forest roads and clearings. In the Hessian national park Kellerwald (Germany) we showed by radio-tracking of brown long-eared bats and Natterer's bats that the maternity roosts were all on sunny hilltops while no such roosts were found in the cool brook valleys. A clear preference of low-density oak tree stands compared to dense beech stands was perceptible in more than 30 maternity roost trees of Bechstein's bat. All these points indicate that bats possibly look for maternity roost sites in climatically more favourable woods. The same situation is found for hibernacula in tree holes, which are preferably in lowlands and river valleys (e.g. Frank & Dietz 1999).

4.6 How many tree holes do bats need?

Tree-dwelling bat species need a high number of natural tree holes in a confined area. For Bechstein's bat, Kerth (1998) determined more than 40 roosts were occupied by a maternity colony within one summer in northern Bavaria. Roost changes could be observed every 2-3 days. In our own studies in the Rhine-Main plain and in the Wetterau (Hesse) we could even state change frequencies of 1.4 and 1.7 days, in which the females permanently changed even with their pups (Bayerl 2004, Dietz & Simon 2004). Additionally there is the fact that a maternity colony of 40 female Bechstein's bats is more or less split between at least two tree roosts simultaneously. All occupied roosts of a maternity colony were in a spatial neighbourhood within a radius of a few hundred metres. For the Philosophenwald in Giessen, which has a size of 20 hectares, we could find 40 occupied Daubenton's bat roosts and more than 60 occupied tree holes of the noctule within a year (Dietz 1993, Frank 1994). It seems that other tree-dwelling bat species need similar densities of roosts (e.g. Schorcht and others 2002, Dense & Rahmel 2002).

Despite the active roost changing, the same roost trees are occupied again and again over the years. If these roosts remain preserved, a roost network can be developed over several decades, which can be occupied over generations. For tree-dwelling bat species there is a clear advantage of an extensive roost network, which is known and available over several years. If you consider roosts are available in trees from 80 to 100 years of age, 250 years old woods have provided tree holes for more than 150 years and they will be established as traditional roost areas for bats.

Accounting for competition for existing roosts between different bat species and between bats and other animal groups, forests must ideally contain at least 10 hollow trees per hectare, which usually corresponds to a density of 20-30 holes suitable for bats per hectare. Stands with this tree hole density can be considered as key areas in the scope of bat conservation.

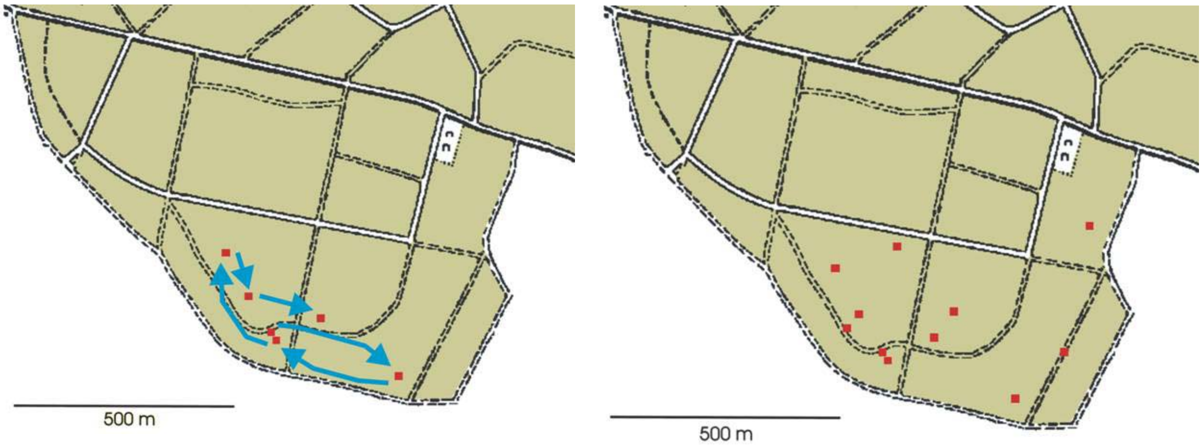


Figure 2 Example of roost switching by a suckling female Bechstein's bat during eight days observed with a radio-transmitter and position of 11 nursery roosts during four weeks in July (Bayerl & Dietz, in prep.)

5. Foraging in woodlands

5.1 Foraging strategies

Prey availability is a second decisive factor besides roost availability for the occurrence of bats. All of the UK's bats prey on insects, which are caught in various ways. To minimise competition with one another, bat species have developed very different and efficient prey capture strategies during the course of their evolution (Neuweiler 1990). These strategies can partly be derived from the morphology of the respective bat. Noctules, for example, have comparatively narrow and long wings that allow fast flight in the free air space, while brown long-eared bats have very broad wings in proportion to their length, which make it possible for the bat to hover like a butterfly through dense vegetation.

Bats do not just catch their prey directly in the open mouth but with the help of the wing and tail membranes. According to their respective flight skills bats catch their prey directly in the air (aerial hawking), by collecting it from leaves, tree-trunks or the ground (foliage gleaning), or even directly from the water surface as seen in Daubenton's bats. A further foraging strategy is the flycatcher-style, which is primarily used by the horseshoe bats (Table 5). The animals hang from an exposed branch and scan their surroundings for passing prey. If they detect a prey object they fly to catch it, afterwards returning to their outlook branch.

When projecting the flight abilities and foraging strategies of the bats onto the spatial niches available in woodlands it becomes clear that all conceivable foraging habitats from the forest floor up to the canopy and beyond can be used by bats. The density of species correspondingly increases with the spatial structures in woods.

Table 5 Foraging strategies of European bat species

Species	Foraging strategy			
	foliage gleaning	**aerial hawking close to vegetation**	**aerial hawking open spaces**	**fly-catching**
Greater horseshoe bat	●	●		●
Lesser horseshoe bat	●	●		●
Daubenton's bat	●*	●*		
Bechstein's bat	●	●		
Natterer's bat	●	●		
Whiskered bat	○	●		
Brandt's bat	○	●		
Common pipistrelle		●	●	
Soprano pipistrelle		●		
Nathusius' pipistrelle		○	●	
Serotine		○	●	
Noctule		○	●	
Leisler's bat		○	●	
Brown long-eared bat	●	●		
Grey long-eared bat	●	●		
Barbastelle		●		

* Daubenton's bat forages close to water surfaces, seldom near to vegetation. It is not known whether they are able to collect insects from vegetation.

5.2 Foraging habitats

Studies in Germany showed that between 10 and 14 bat species can regularly be recorded in deciduous and mixed woodlands of several hundreds of hectares in size (e.g. Meschede & Heller 2000, Meschede and others 2002). Woodlands with a high proportion of deciduous trees, particularly oak and beech, show significantly more bat species than coniferous forests. The activity of a species is also higher in deciduous woodlands, as shown by the example of the Bechstein's bat in the Hessian Spessart (Figure 3).

Besides a high proportion of deciduous wood bats favour light, old (> 140 years) woods with younger (> 80 years) areas of higher tree trunk density and occasional regeneration thickets. Thus, there is also a vertical element to the woodland structure, which is especially interesting for species foraging in narrow spaces. In addition, lakes and ponds, small pools, brooks and rivers, clearings and glades are essential foraging habitats in woods, as are staggered, south-facing exposed edges of the forest. Woodland areas with complex vegetation structure and abundant water may be key areas for bats.

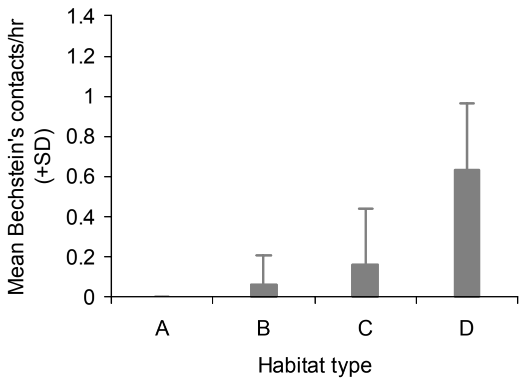


Figure 3 (left) Mean activity density for the Bechstein's bat in ultrasound detector contacts per hour for four habitat types (A = riverine meadow without trees; B = open country with fruit and hay meadows; C = coniferous dominated woodlands; D = deciduous dominated woodlands). (right) Typical Bechstein's bat feeding area in a light oak forest. Photo M König

5.3 Prey variety and home range

The prey spectra of bat species depends on the foraging strategy, the season and the habitat. An examination of droppings of greater horseshoe bats for example showed a comparatively high proportion of craneflies during spring. In May they preyed increasingly on cockchafers, and later in the summer on dung beetles and dor beetles. Moths were of high importance during almost the entire summer (Jones 1990). By comparison, the lesser horseshoe bat cannot cope with large prey such as cockchafers due to its own body size. It eats smaller moth species than the greater horseshoe bat (Beck 1995).

The more diverse the foraging strategies of a bat species are, the more diverse its prey. Fragments of more than 16 insect orders were found in the droppings of Bechstein's bats, which glean prey from vegetation as well as catching insects in the air (Wolz 2002). There were also significant amounts of non-flying development stages of insects such as butterfly caterpillars and beetle larvae. Analysis of Bechstein's bat droppings also reveals that this species gleans from the ground as well as from the vegetation, taking flightless prey groups such as spiders and grasshopper larvae. Nocturnal flying insects caught by Bechstein's bat are primarily soft-skin insects, like crane flies and lacewings. In contrast, the Natterer's bat, which also forages predominantly in woods, eats far fewer moths but more flies and spiders (Shiel and others 1991, Gaisler & Dietz 1995).

Variations in the prey taken can also be found within a species depending on the various landscapes it inhabits. Noctules living close to water feed more often on swarming insects associated with water than those noctules that live primarily in urban landscapes with little open water (Gloor and others 1995).

It is obvious from the prey spectrum of the Daubenton's bat that this species is very restricted to water habitats. Chironomidae or other insects whose larval development takes place in the water are by far the predominant prey (Swift & Racey 1983, Taake 1992).

The barbastelle is closely associated with small moths, feeding primarily on the orders Pyralidae and Arctiidae (Sierro & Arlettaz 1997). In comparison, long-eared bats, which also mainly feed on moths, catch primarily Noctuidae.

Table 6 Overview of the most frequent prey groups found in British bat species. If a group is not marked with ● it does not mean that it is never eaten.

Species	Moths	Beetles	Flies	Midges	Lacewings	Caddis flies	Spiders
R. ferrumequinum	●	●		●			
R. hipposideros	●			●	●		
M. daubentonii				●	●	●	
M. bechsteinii	●	●	●	●	●		●
M. nattereri		●	●	●	●		●
M. mystacinus			●	●			●
M. brandtii	●		●	●			●
P. pipistrellus	●			●		●	
P. pygmaeus				●			
P. nathusii				●			
E. serotinus	●	●	●				
N. noctula		●	●	●		●	
N. leisleri	●		●	●		●	
P. auritus	●	●		●			
P. austriacus	●	●					
B. barbastellus	●						

[Barlow 1997, Beck 1995, Gaisler & Dietz 1995, Gloor 1995, Jones 1990, Sullivan and others 1993, Sierro & Arlettaz 1997, Shiel and others 1991+1998, Swift & Racey 1983, Swift and others 1985, Taake 1992, Waters and others 1995, Wolz 2002]

The foraging strategies, prey types taken, and the bats' flight abilities influence the size of home ranges of bat species living in forests. The noctule flies quite fast and can travel long distances high in the air in a short time. It frequently travels up to 20 kilometres to foraging habitats (Kronwitter 1988, Le Marec 2003). Leisler's bat behaves similarly (Schorcht 2002). In comparison Daubenton's bat is closely related to water and the distance between the foraging area and the roost tree is usually less than 4 kilometres, although distances over 10 kilometres are possible (personal observation, Dietz & Simon 2003). Comparable distances are known for whiskered and Brandt's bats and the barbastelle (Dense & Rahmel 2002, Simon and others 2004). Foliage gleaners such as Bechstein's bat are able to forage close to their roosts if the woods provide various structures. Depending on the available insects, they can forage along woodland paths, forest edges and in clearings, as well as gleaning on vegetation structures from the ground up to the canopy. Because of this ability Bechstein's bat hardly ever flies more than a kilometre away from its roost within the woods. However, it also covers distances of five and more kilometres between roost and foraging area in more open habitats (Bayerl 2004, personal observation).

5.4 Nutritional requirements

The quality of a foraging area is determined by its prey density. If the prey density falls below a certain value, the relationship between the energy expended during the search flight and the energy gained from feeding becomes unfavourable. A bat must then change foraging area, provided that it has the possibility to do so. This indicates that a sufficient system of foraging areas must be in a favourable spatial arrangement for the bat.

The food requirement of bats in temperate zones is subject to significant seasonal fluctuations correlated with the reproductive cycle. There is an increased demand by the females during the reproductive phase at advanced pregnancy, reaching a climax during lactation phase. This is reflected in the higher food consumption by lactating females. Prey intake increases by about 40-50 % from pregnancy to lactation (e.g. Anthony & Kunz 1977, Kunz 1974). Pregnancy and lactation of bats in temperate zones are synchronized with the period of the highest food availability (e.g. Racey & Swift 1985). If the food density is too low during the period of maternity, few young are raised successfully.

Food shortage can naturally be caused by unfavourable weather conditions, for example rain and low temperatures. However, more threatening is the loss of insect rich habitats.

Woodland stands that have a high arthropod abundance either during the whole growing season or during certain periods when bat prey is rare in most other places are key areas for foraging bats. Single ancient trees may have the same function and can be considered key elements in bat habitats.

6. Methods for woodland managers to identify elements of woodland important to bats

The identification of key areas and key elements for bats in woodland should follow two steps described as follows.

6.1 1st step: Recognising potential habitats

To recognise habitats of bats in woods, you must consider their way of their life and try to assess the woods from the viewpoint of the bats. Ask the questions:

Where are the oldest deciduous woods? From about 80-100 years of age onwards deciduous woods have progressively more treehole development and woodpeckers start to make brooding holes. Also bark injuries and branch demolitions have occurred. A high hole density is likely if the trees have reached an age of about 140 years, provided that the woods have not been managed too intensively. This is often the case at sites with limited productivity.

Where can you expect a sufficient insect density? Start with older and well structured areas. A high insect density can be found in woods with several levels of different structures, as well at water, at forest edges, and in glades and clearings.

What potential flight-paths exist for bats? Bats very frequently fly along landscape structures like brooks, tree avenues, hedges, forest edges and woodland paths, and also flat elements like fruit orchard meadows and field copses.

Besides their own knowledge of the area there are databases of records from forest wardens and nature observers in many forestry offices, which help to answer these questions. This includes the records of the forest industries themselves, with details on tree species' distributions and age of stands. Furthermore there are aerial pictures, topographical maps (1:10,000 or 1:25,000) or maps of biotopes.

6.2 2nd step: Active search for roosts, flight paths and foraging habitats

Once you have an overview of the woodland then observation points or sample areas can be chosen in a second step. At this stage there are methods that can be successfully used by practised laymen.

6.2.1 Mapping of tree holes

A survey to map tree holes should be done in conditions of high visibility. Sunny, clear weather from November until March or April, when trees have no leaves is preferable. For a systematic procedure it is recommended to subdivide larger areas into smaller patches (100 x 100 metres) with ribbon markings before mapping begins. The investigation area should be surveyed from outside to the inside within a day, so that the complete trunk area of each tree is sufficiently visible with the sun at the back.

At first the search can be carried out with the naked eye, but for more detailed inspection binoculars are needed. The time necessary for mapping varies greatly and depends on the target. A systematic mapping of black woodpecker holes in hall-like common beech woods requires less time (30 minutes per hectare) than a complete mapping of holes of smaller woodpecker species in oak dominated woodland (up to 2 hours per hectare). However, mapping of tree holes can never be complete. Even with thorough searches some holes will be missed. In addition, new holes arise in the course of the years and require a regular update.

Less systematic day inspections in leaf-free woods can also give some indications about hollow tree densities too.

An exact recording of the hollow trees on a map is important and should be done with the help of a GPS device. Marking the hollow tree makes it easier to refind the hole and can be of use for forestry workers as a reminder for the preservation of the tree or as the basis of a long-term hole record for management purposes. A hollow tree can be marked with different symbols, for example numbers, used to portray the presence of woodpeckers, bats or simple locations. If made with spray colour these markings must be replaced at regular intervals.

Aluminium badges nailed to trees with aluminium nails have proved useful in our investigations on long-term development of tree holes and their residents. Each badge is unique, making it possible to identify a certain tree unequivocally. Considering a tree’s growth the nails should be embedded only up to half their length to prevent early loss of the badge after a few years.

6.2.2 Finding occupied trees by indirect features

Trees can be examined with binoculars for traces of bat roosts. The most striking evidence is staining from excrement and urine beneath the entrance hole, which can develop to a long brown stripe of metre or more. However, this does not apply to all bat roosts in tree holes and sometimes a similar stripe arises without the presence of bats. In addition, dark edges can be caused by bats flying in and out (grease from the wing membranes) or white crystals of urine salts might be also recognizable at the entrance. Small fragments of droppings on the trunk or on surrounding vegetation might indicate currently occupied bat roosts.

6.2.3 Listening for social calls from occupied tree roosts

Noctules and Leisler's bats can be very noisy in their tree roosts. These social calls can be heard well without technical aids, sometimes at distances of over 50 metres. They sound somewhat like annoyed tits or young woodpeckers. They can be exceptionally loud before emerging in the evening or after returning in the morning. During very warm temperatures the calls can be heard almost all day long, primarily during maternity time in June and July and during mating time in August and September. Occupied roosts of noctules or Leisler's bats can be found in tree hole rich forests by simply walking in the woods at these times.

Even hibernation roosts can be found with the help of social calls. Some noctules frequently wake up from hibernation on mild, sunny winter days. The lethargic bats are bothered by the activity of their roost mates and answer with high "Zieh" calls which can be well localised.

6.2.4 Inspection of existing bat boxes

The inspection of available bat or bird boxes represents a method with relatively little effort. It can give an overview of the abundance of species of tree-dwelling bats. A determination of the species can be carried out easily. Nevertheless, if there are no bats in the boxes it does not mean that there are no animals around.

6.3 When to employ a bat specialist?

For the exact recording of the abundance of bat species, specific searches for occupied tree roosts (primarily maternity colonies), and the habitat use of different species in an area, the professional work of specialists is required. These should use a combination of methods ranging from detector surveys and netting, to tree hole inspections and radio-tracking depending on the aim, to achieve reliable results which are relevant for conservation and management. Time expenditure for the application of such methods can be high and therefore a systematic and appropriate application is usually not possible for unpractised and time-limited volunteer bat workers. For reasons of animal welfare the handling of animals and the use of invasive methods requires professional experts (Brinkmann and others 1996, Wilson and others 1996, Mitchell-Jones & McLeish 2004, Dietz & Simon 2003).

To estimate or investigate the bat fauna of a woodland we propose three approaches with growing intensity and data quality:

First approach: Survey of potential roosts

This survey has two elements. The first is an evaluation of the forest stands by tree species composition and age (Limpens and others 1991) using the criteria mentioned in the previous section (First step). The selection of appropriate stands should be based on forestry maps and plans. The second element is to ascertain the abundance of potential roosts in the stands evaluated to be most attractive for bats. This fieldwork is necessary as woodlands of a certain forest type can have very different numbers of potential roosts. For example the tree hole density of old-growth stands in a biosphere reserve in western Germany varied from zero to 19.2 tree holes per hectare (Pfalzer & Weber 2002). Procedures for finding and mapping tree holes and checking the presence of bats are described in the previous section (Second step).

This first approach to a woodland bat survey does not need bat specialists and can be done by foresters or volunteers.

Second approach: Identification of species and rough estimation of their abundance

To identify the occurrence of bat species and estimate their abundance in a certain forest stand it is necessary to make a series of sample surveys with detectors and nets. For a rough estimation of the fauna we personally think it is appropriate to make 5 detector surveys and 2-6 netting nights, each with nets of 80-100 metres in total length, during spring and summer seasons.

This second approach should be done by specialists who are experienced in the use of bat detectors and nets. These bat specialists may be amateurs or professionals.

Third approach: Investigation of the bat species composition and abundance

An investigation of the bat fauna in a woodland to evaluate the species composition and give a reliable estimation of the species' abundances requires a careful look at all species and their maternity colonies. It is important to include also those species that only forage in the woodland and roost outside e.g. in buildings. Such investigation will rely on the use of all appropriate survey methods, including radio-tracking to find roost sites of colonies (see above). In addition it is necessary to know which bat species occur in the region and in the particular forest types like the investigated stands. If this is not done, an evaluation of the results of the investigation or woodland management practices is incomplete.

This third approach is best done by professional bat experts.

This proposal of a stepwise approach to the bat fauna of woodlands is based on personal experience with survey methods and site-related investigations of bat populations. However, it is not yet proved on a larger scale with different persons or in other countries. Certainly more research is needed to evaluate this approach in general and the appropriate number of field surveys (detectors, nets etc.) in particular. It is also necessary to know about the specific bat fauna of certain forest types in Europe, pristine or under forestry management, but there are little data currently available.

7. How does woodland management impinge on woodland bats?

The chapters on the roosting and foraging behaviour of bats have shown that older deciduous and mixed woodlands are the primary forest types that show a high roost and foraging habitat potential as long as they provide various vertical and horizontal structures. Forest management practices can immediately change these qualities in favour, or to the disadvantage, of the bats. The surroundings of woods also affect the abundance of bat species that can be found in the woods either directly or indirectly. Movement between different woodland areas and the abundance of species is influenced by the structure of the landscapes, as explained earlier.

7.1 Density of roosts

Bats require a high natural density of tree holes in deciduous and mixed woodlands. This increases in woods from the age of 80 to 100 years and is greatest in permanent forests, which are even older. Age and decomposition phases offer the most optimal prerequisites for hole development and emergence of crevices and loose bark. With advancing age, trunk diameters increase and with that the stability for larger hole volumes. Also, the prerequisites for the beginning of rotting and for the production of nesting and roosting holes by woodpeckers improve. In addition, the amount of dead wood increases with advancing age of woodlands and standing dead wood is very important for bats and also for other tree-dwelling animals (see above as well as McClelland & Frissel 1975, Scott 1978, Hohlfeld 1995 and Frank 1997).

All prerequisites to the emergence of hollow trees mentioned before can be influenced by management:

- **Structure of woods and tree species composition:** Bat roosts can be found predominantly in deciduous trees, with conifers playing only a very subordinate role. The number of tree holes will be drastically reduced by the transformation of deciduous into coniferous woods.By contrast, the density of roosts can be promoted in a long-term by an increase of deciduous trees.
- **Age of the wood:** The tree hole density increases with the advancing age of the woods. If beech and oak woods are already harvested intensively at between 100 and 120 years of age, insufficient tree hole densities and amounts of loose bark can be reached. The older the woods are the higher is the density of tree holes.
- **Management intensity:** Tree hole densities can be promoted or avoided depending on the intensity of the management practices. If stunted, damaged, and dying trees are taken out at regular fellings in a cycle of 5-7 years, a considerable amount of potential hollow trees is missed. However, potential roost trees can be promoted by targeted protection when they are young, similar to valuable wood trunks.
- **Protection of hollow trees:** The most direct form of a negative influence is the felling of hollow trees in the context of management. A consistent protection of all recognizable hollow trees immediately promotes the natural roosts on offer and the value for bats.
- **Protection of standing and lying dead wood:** Removal of standing and lying dead wood affects the hole density directly, if roost trees are concerned. Furthermore there is an indirect influence by deterioration of the habitat for hole producing organisms like woodpeckers. An increase in the density of dead wood causes a higher potential of roosts (e.g. behind loose bark).

The aspects mentioned here can be verified by numerous examinations from Germany. In the Kellerwald national park in northern Hesse all of the 40 bat roosts that could be found in tree holes were in deciduous trees of low economic value. The predominant number of these trees would have been taken out at regular forestry management campaigns (Dietz, unpublished). Zahner (2001) shows for Bavaria, that the complete tree hole density is significantly higher in beech wood reservations without forestry exploitation than in managed woodland. Hohlfeld (2001) refers to the clearly higher number of tree holes in protected forests in comparison to economically exploited woods in Baden-Wurttemberg. He showed a correspondingly higher number of tree-dwelling birds in protected forests. According to Zahner (2000), the proportion of birds breeding in tree holes is therefore an indicator for hole rich and old woods. Estimates for the hole density of protected and managed woodlands are also available. Noecke (1991) for example determined a hole density of 5.7-7.1 holes per hectare in managed beech woods of North Rhine Westphalia for the age-groups of 125-179 years. In comparably old natural woods she could find a density of 15.7 holes per hectare. Zahner (2001) gives density results for managed beech woods of 4-11.2 per hectare in comparison to 15.2 holes per hectare and 34.6 per hectare for beechwood reservations. For the Philosophenwald in Giessen (in the middle of Hesse), which has been protected since 1987 and managed in the context of traffic safeguarding only since 1980, Frank (1997) could find a density of 21 holes per hectare.

7.2 Foraging areas

- **Tree species composition:** As seen for the density of roosts, the tree species composition plays an essential role. Transformation of deciduous to coniferous woodland in pure stands clearly lowers the quality as foraging areas, since both the preferential foraging habitat structures are missing and the insect density decreases through the course of the year. Support for deciduous and mixed woodlands positively affects the occurrence of bats.

- **Structure variety:** Structural richness is limited in even-aged woods. Accordingly, the foraging habitat variety is also limited which immediately affects the activity density and diversity of species. An increase in the vertical structure of stands promotes the niche variety for different bat species. Clearings, structured forest edges and water also positively affect the diversity of species.

- **Pesticides:** As a final element of the food chain, bats are indirectly concerned by the accumulation of environmental pollutants in their fat tissues. A heavy body-burden due to the common use of pesticides like lindane and chlorinated hydrocarbon substances led, presumably, to drastic collapses of populations in the sixties and seventies of the last century. The toxins could be found in high concentrations in the fat tissue even of suckling pups. The load has reduced significantly in the meantime but single applications of pesticides in woodlands can immediately affect animals, e.g. if greater horseshoe bats take affected butterflies from the vegetation. The use of pesticides moreover lowers the food density directly. For these reasons woodland managers should use pesticides very carefully. At best, pesticides should be applied only in exceptional cases for short times to reduce an economically relevant tree pest.

7.3 Protected areas

The conservation of woodland bats is possible under forestry management, if management practices take account of the animals. Because of the ecology, sociology and migration of bats it is impossible to protect populations through the establishment of a certain limited protected area. Therefore protected areas without any timber harvest or other management have a limited value for bat conservation in general but they are highly welcomed as reference areas, where a natural situation and the associated species' composition can be studied.

Protected woodland areas with an undisturbed bat fauna are particularly important to prove the consequences of current forestry management in other woodlands of the same region. This function as reference areas for the evaluation of sustainability of woodland management is the reason why a network of set-aside protected woodland areas should be taken as inherent elements of sustainable forestry practices. Such protected areas for reference purposes may be under forestry administration and they should be separated from the Natura 2000 site network, which has the aim of certain habitat and species conservation e.g. for the bats of Annex 2 of the EU Habitats Directive.

7.4 Artificial roosts

7.4.1 Bat boxes

The idea of compensating for the loss of bat roosts in forests by the erection of artificial boxes is more than 100 years old (Meschede & Heller 2000). Issel & Issel (1955) were the first to investigate scientifically the occupation of bat boxes in the field. Since then many surveys and investigations on bats in boxes have been done. Offering special bat boxes as artificial roosts has become popular in bat conservation in Europe and America (e.g. Haensel & Näfe 1982, Richarz 1986, Tuttle & Hensley 1993). The enormous amount of literature related to bat boxes was first compiled by Krzanowski (1991).

Of the 21 species regularly occurring in central Europe, 17 have been observed to roost in boxes; 10 or 11 of them also reproduce there (Table 7). In addition, the following species were found in bat or bird boxes in other parts of Europe: Northern bat *Eptesicus nilssonii* in southern Sweden (Gerell 1985), Kuhl's pipistrelle *Pipistrellus kuhlii* in France and Spain (Tupinier 1981, Benzal 1990) and parti-coloured bat *Vespertilio murinus* in Russia (Kurskow 1968, Kowalski & Lesinski 1994). There is no indication that horseshoe bats use bat boxes regularly. As Kolb (1957) pointed out rhinolophids prefer to keep some space between each other and therefore will avoid going into a narrow box as a colony.

Table 7 Use of bat boxes by bat species in Germany (after Meschede & Heller 2000)

Species	single specimen	mating groups	maternity colonies
Myotis daubentonii	●	●	●
Myotis dasycneme	●	●	
Myotis mystacinus	●		●
Myotis brandtii	●		●
Myotis emarginatus	●		
Myotis nattereri	●	●	●
Myotis bechsteinii	●		●
Myotis myotis	●	●	
Nyctalus noctula	●	●	●
Nyctalus leisleri	●	●	●
Eptesicus serotinus	●		
Pipistrellus pipistrellus	●	●	●
Pipistrellus pygmaeus	●		●
Pipistrellus nathusii	●	●	●
Plecotus auritus	●	●	●
Plecotus austriacus	●		
Barbastella barbastellus	●		●

Types of boxes used by bats

There are principally four types of boxes used by bats:

- hollow bird boxes with the entrance at the upper third of the box;
- hollow bat boxes with the entrance at the lower quarter of the box;
- flat bat boxes which form a crevice to be entered from below and;
- large bat boxes suitable for hibernating bats.

Many variants are described in the literature (reviewed by Haensel & Näfe, 1982, and Kuthe & Ibisch, 1989). Experiences with the different bat boxes are also diverse. However, it is generally agreed that specialist bat boxes are much more suitable for bats than bird boxes (Bäumler 1988, Nagel & Nagel 1988, Schwarting 1990, Schwenke 1988b). Most bird boxes are available for bats only after the birds' breeding season (Schlapp 1990). Bechstein's bat, for example, was present in 1% of bird boxes in a Bavarian forest during the birds' breeding season, but was observed in more than 25 % of the boxes afterwards (Schlapp 1981). Hollow bat boxes are not appropriate for birds and songbirds manage to nest in them in only a few cases (Haensel & Näfe 1982).

European bat species show different preferences for bat boxes. Nathusius' pipistrelle and Brandt's bat prefer crevices and are recorded mostly if flat bat boxes are offered as roosts (Heise 1983a, Dieterich & Dieterich 1988). Other species, such as Bechstein's bat and noctule, need more space and prefer hollow bat boxes, at least for colonies (Kerth 1998, Heise & Blohm 1998).

Bat boxes are usually made of wood or concrete mixed with 70-80 % sawdust (Meschede & Heller 2000). Wooden boxes were preferred in eastern German woodlands (e.g. Stratmann 1973, Schmidt 1977, Heise 1983a, Iffert and others 1989, Labes 1989). Their 'lifetime' is about 10-12 years (Hackethal & Oldenburg 1983) but this can be extended by a cover of roofing felt (Heise 1980). Other authors claimed the concrete boxes to be more suitable to bats (e.g. Henze 1968, Gerell 1985), because they are more resistant to rain and woodpeckers and they survive for about 25-30 years (Henze 1963, 1991). The microclimate in the box is to some degree dependent on the material but this seems to be less important to bats (Meschede & Heller 2000). Plastic is not appropriate as bat box material because its surface is too smooth for bats to climb it and they may become trapped in the box (Taake & Vierhaus 1984).

It is an advantage that bat boxes give room to the bats above the entrance in a similar structure to woodpecker holes, which are enlarged at the top by rotting processes. Bats can hang in the dark above the entrance and are well protected from draughts and predators (Dieterich 1982). The form of the entrance seems to be of minor importance. However, it must not be too small. For example pregnant Daubenton's bats have difficulties entering a box through a round hole of 26 millimetres diameter or less (Dieterich & Dieterich 1991). Pregnant noctules avoid entrances narrower than 15 mm (Heise & Blohm 1998).

The construction of a bat box should also consider bat faeces, which might accumulate quickly when the box is occupied by a colony (Laufens 1973, Heise & Blohm 1998). Boxes where faeces can fall out are most appropriate. Other types must have enough space below the entrance so that a bat must neither crawl through faeces nor the entrance become blocked

(Nagel 1982, Leitl 1995). If bats are forced to come into contact with their faeces and parasites they tend to change roost site (Stratmann 1978, Wolz 1986).

Experience with large bat boxes and their suitability as hibernation sites is limited. In Germany there are some observations with the noctule (Schwarting 1994b, Dieterich 1998, Wissing 1996b) and a single one with three specimens of Leisler's bat (Meschede & Heller 2000). Some noctules have been found dead in such boxes indicating that the walls were too thin to prevent the animals from being frozen.

Exposure of bat boxes

There are some indications that the percentage of boxes occupied by bats grows with the number of boxes available to these animals. Schmidt (1990) raised the number of bat boxes in a eastern German pine forest continuously over some years. He observed a growing number of bat records until an abundance of about five bat boxes per 10 hectare was reached at sunny and semi-shaded sites. It is proposed to put up at least 10-20 bat boxes in one place to give bats the opportunity to use the most convenient ones and change roosts from time to time (Heidecke 1989, Heise 1983a, Henze 1963, Roer 1971, Schmidt 1977). Accumulations of about three boxes each are not necessary in general, but may support social behaviour in some species, for example the noctule (Oldenburg & Hackethal 1989, Schmidt 1977). If boxes are used which are suitable for both bats and birds, one should hang them up in groups as the territoriality of a breeding bird couple will chase other birds away, so some boxes will be kept free for bats (Haensel & Näfe 1982, Henze 1963, Roer 1971). Such groups of bat or bird boxes should be put in place at intervals of 50-100 metres (Heidecke 1989, Schwarting 1994a, Dieterich & Dieterich 1997b, Schmidt 1998).

Proposals for where to distribute bat boxes are very diverse. In woodlands some authors prefer places near forest roads, paths or forest edges, others put boxes right into the forest stands. It is proved that each particular place for a bat box may influence the probability of colonisation by a certain bat species (Leitl 1995).

In Germany, bat boxes that were actually used by bats were at heights of between 1.5 metres and 6 metres (Meschede & Heller 2000). The noctule seems to prefer boxes more than 4 metres above the ground due to its style of flight departure characterized by jumping downwards to get some speed first (Stratmann 1978, Kronwitter 1988a, Heise & Blohm 1998).

In practice the height of bat boxes should be dependent on the specific place. In general boxes should be easily available for maintenance, at least with a portable ladder. The most convenient and effective heights are 2.5 to 4 metres. However, along forest roads and public footpaths it could be safer and the disturbance risk to bats lower if boxes are fixed higher in the trees (Meschede & Heller 2000).

The direction of exposure of bat boxes is of minor relevance. For years it has been recommended to put them up in south- or east-facing directions and so most recent bat boxes have such exposures. Most important to the animals is the temperature inside the boxes, which is dependent on the exposure to sunshine. Bat boxes exposed to the north get shadow from the tree's trunk for most of the time. Therefore in general bats prefer boxes directed to the southwest, boxes to the south have moderate attraction and those directed to the northeast are of little interest to bats (Fuhrmann 1992). In spring and autumn bats prefer to roost in boxes exposed to the sun. As an example Nathusius' pipistrelle uses boxes at sunny places from April to June (Oldenburg & Hackethal 1989). During hot seasons however, bats avoid those boxes exposed to the sun (Schmidt 1990, König & König 1995), as temperatures inside get too hot (Nagel & Nagel 1993).

In Bechstein's bat it was shown that females preferred bat boxes during the maternity period, but stayed in natural tree holes before and after that time. Although individual bats of a colony changed their roost every couple of days, the warmer bat boxes were always home to more bats than cooler ones. In late summer the boxes had significant higher temperatures inside (11.8 °C on average) compared to natural tree holes (10.3 °C on average) (Kerth and others 2002). This behaviour is in accordance with the bats' biology. Generally they want to cool down as fast as possible when they enter their roost, as the low body temperature at rest saves energy and is the key factor to survive periods with little foraging success. Only females that are pregnant or lactating must maintain high body temperatures all day, because if they cool down the young's growth will take longer or may stop. Therefore maternity colonies are predominantly found at warm roost sites.

The space in front of a bat box should not be too covered as most bats like an open area for swarming and landing at the entrance (Issel & Issel 1955, Nagel & Nagel 1988, Oldenburg & Hackethal 1989, Schmidt 1977). However, bat boxes which are hidden in dense vegetation can be used by Bechstein's bat, Natterer's bat, and the brown long-eared bat in particular (Leitl 1995, Schwarting 1994a, Wissing & König 1995).

Pros and cons of bat boxes

The results of investigations on the occurrence of bats in bat and bird boxes show that these artificial roosts are accepted and used by almost all European bat species. However, experts have not yet reached consensus on whether bat boxes really enhance populations or just cause a shift in roost occupancy. Some authors interpreted their results to be based on a higher roost quality of the boxes compared to natural roosts in trees, so that the bats present in the area changed their preferences and became more visible to observers (e.g. Schwarting 1992, Nagel & Nagel 1993). In other cases, natural roost sites in trees were very rare in an area and the frequency of bat observations increased significantly after bat boxes were installed. This was documented by Schmidt (1990, 1994a, 1994b) in pine forests in eastern Germany and by Pryswitt (in Dieterich and others 1998) in deciduous forest in northern Germany.

There is also a debate about the impact of the concrete/sawdust material of bat boxes on the thumb and toenails of bats. Some observations suggested the material might be unnaturally hard and cause friction. As an effect, toe- nails become too short and the animals may be handicapped when trying to climb a surface. However, the debate is still open and the adverse effect has not been scientifically proven yet (Vierhaus & Schröpfer 1984, von Helversen 1989b, Fuhrmann 1989, Nagel & Nagel 1993, Weishaar 1995, Dieterich & Dieterich 1997a, Gebhard 1997).

There is more discussion on bat boxes, which can be summarized in an overview of the positive (Pros) and the negative aspects (Cons) of bat boxes:

Roost type:

Pro: Bat boxes offer new or additional roosts to bats. The animals have free choice to use them, if the boxes are appropriate. As long as nothing is known about mortality in bats there is no concern about dead bats in boxes.

Con: Bat boxes do not have the same features as natural roosts in trees. The artificial material, the microclimate inside, and easy access by predators like the pine marten may be harmful to bats. The finding of frozen and other dead bats in bat boxes is alarming.

Life time:

Pro: Bat boxes certainly need care and in the course of annual maintenance destroyed boxes should be replaced. This is no problem for bats as they find their traditional roost by its locality, not by its smell.

Con: The lifetime of a bat box is about 10 to 20 years while a tree with a woodpecker hole can stand for more than 100 years. When bats have taken a bat box as a traditional roost its lifetime is almost over. As was seen in Germany, regular care for bat boxes in woodlands is exceptional (Meschede & Heller 2000). Bat boxes might therefore disrupt roost site traditions in bats.

Selectivity:

Pro: Bat boxes are appropriate conservation measures for nearly all bat species (Table 6). Some species may profit in particular, but if different types of bat boxes are used in a woodland all bat species should have the chance to find an appropriate new roost.

Con: In most woodlands all bat boxes are of the same type for economic reasons. In practice, a very limited number of species benefits from bat boxes (for example noctule, Nathusius' pipistrelle, brown long-eared bat). Those species that are endangered and really need help will either move into boxes if they have an abundant population anyway (for example Bechstein's bat) or they generally use bat boxes on very rare occasions (for example barbastelle).

Competition:

Pro: Additional roosts like bat boxes have very little influence on the bat species' community. The occurrence and abundance of the species are dependent on the specific food availability.

Con: New roosts that are especially utilized by certain species or individuals will have an impact on inter- and intraspecific relationships of the bats. As consequence the naturally occurring bat community or the system of territories of individuals and colonies may be changed. As nothing is known about such effects (Gebhard 1997) one should follow the precautionary principal and do without bat boxes.

Monitoring:

Pro: Bat boxes make the bats visible. Therefore surveying of bat boxes can be included in bat monitoring schemes.

Con: Bats use bat boxes selectively. Some species are often found in boxes, other rarely or never. Additionally there is a highly seasonal dimension to the occupation of bat boxes by bats, which makes it difficult to compare results from bat box surveys in different times of the year. Therefore survey of bat boxes should only be one method among others to monitor bat populations and bat communities.

Woodland policy:

Pro: Woodland managers and land owners get involved with bat conservation as they distribute bat boxes in their woodlands.

Con: Bat boxes are used by woodland managers as a cheap and easy compensation for true conservation measures, which would enhance not only bat populations but woodland biodiversity in general in a much longer term. A bat box in a single age stand forest with little structure is a symbol of misguided conservation action.

7.4.2 High seats

Large high seats of hunters can offer appropriate roost sites to bats, especially to species preferring crevices and narrow hides. Investigations in three regions of Germany showed a high colonization rate of high seats particularly near forest edges (Hübner & Papadopoulos 1998, Hübner 1999, 2000, Papadopoulos 2001). The authors recommended equipping large high seats with different bat boxes and artificial crevices wherever possible. Such measures may help bat species that mainly occur in towns and villages to find adequate roosts nearer to the woodlands where they forage (Hübner 2000). Crevices on high seats are also used by other mammals (dormice, mice), birds (tree creeper), and wasps (Hübner 2001).

7.4.3 Artificial hibernacula

The need for underground hibernacula depends on the migratory and over wintering behaviour of woodland bats. Species having maternity colonies in British forests can be divided into three groups: those hibernating above ground in tree holes or buildings and travelling for several 100 kilometres if necessary (noctule, Leisler's bat); those migrating usually less than 50 kilometres and predominantly hibernating in underground sites with temperatures above zero (Daubenton's bat, whiskered bat, Brandt's bat, common pipistrelle); and those usually migrating less than 20 kilometres but their main type of specific hibernacula is not yet known (Natterer's bat, Bechstein's bat, brown long-eared bat, barbastelle). Most specimens of these latter species may hibernate in trees although some occur in underground sites during frosty periods. It is also unknown to which group the soprano pipistrelle belongs.

Underground hibernacula do not have to be near to a woodland as bats can migrate over a distance of several kilometres at least, and they have communication systems by which they get the information as to where traditional hibernation sites are (Simon and others 2004). In general only a small proportion of such hibernacula are known to people. Even in a species like the greater mouse-eared bat, which is comparatively easy to monitor in its maternity colonies and hibernation sites, a comparison of the German population data revealed that it is not known where more than 90% of the individuals (successfully) hibernate (Geiger 2002).

7.4.4 Personal conclusions

In our view bat boxes are a good instrument to survey for the occurrence of bat species in a woodland and to observe certain colonies or marked individuals. The conservation value of bat boxes is limited to areas without old trees, where natural bat roosts are missing. In such areas bat boxes can be helpful for bats to survive until such time when trees become old enough to have holes and crevices. However, bat boxes should only be used if it is ensured that somebody cares for them for many years. Bat boxes should not be used in old-growth forests and core areas of nature reserves or national parks.

The creation of artificial bat roosts should never be an argument for the erection of high seats for hunters. If special structures for bats are attached to high seats local bat populations may have some benefit from using them. But this effect is low compared to the very probable effect of changing the current woodland bat community by favouring species normally roosting in houses. Species that prefer crevices and are endangered by a lack of suitable roosting (for example Bechstein's bat and barbastelle) are not improved by such structures on high seats.

There is no need for the creation of more underground hibernation sites within woodlands. Conservation efforts for bats in woodlands should concentrate on above-ground roosts in trees, which can be used by bats during summer and winter.

8. Examples of good woodland management practice

Some national and regional programmes of woodland management have a target of adaptive timber harvest and maximum care of the forest fauna (Meschede & Heller 2000). However, none evaluated aspects of bat conservation in practice. Consequently, there are no examples of bat-friendly woodland management practices available so far. It is a challenge for future bat research to investigate the impact of certain management practices or programmes on bat populations and bat communities of the various forest types found in Europe. Basic data for such an evaluation are collected by many local bat surveys in woodlands, especially investigations in national parks and other unexploited forest areas.

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10. Authors

Dr. Peter Boye became fascinated by mammals at the age of 17. He studied biology in Hamburg and Bonn and finished his university education with a masters thesis on the Alpine snow vole. After some years of working as a consultant in animal ecology he was employed by the German Federal Agency for Nature Conservation. Since 1993 he has been busy with international animal species conservation, especially of migratory birds and bats. Besides his job he kept in touch with field mammalogy and wrote a PhD thesis on population ecology of rodents in arable land.

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Markus Dietz started working with bats in 1992 with his diploma thesis about the resource utilisation of Daubenton's bats in Giessen. After this he was responsible for a "Bats in buildings"project that should improve the protection of house dwelling bats efficiently, for example by working out plans for the construction of bat roosts in buildings. During the past couple of years he has built up a private Institute for Animal Ecology and is working on intensive field studies of bats in forests, especially in national parks and Natura 2000 sites. In his "free time" he is preparing a PhD at the University of Ulm about the different feeding strategies of female and male Daubenton's bats.

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