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Guidance on the conservation and management of critical feeding areas and commuting routes for bats

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Contents

Key recommendations

As well as general information on habitat management and conservation of feeding areas of bats, Chapter 6 of this guidance contains a detailed review of available knowledge for each European bat species.

Given that many bats benefit from certain types of habitat management, the following points summarise the main recommendations for conserving and managing important feeding areas and commuting routes:

- During the planning process and when planning other land-use projects, seek up-to-date data on bat species and their habitats (roosts and feeding areas) in the area.
- Pay attention on the connectivity of landscape, especially between roosts and feeding areas.
- Avoid fragmenting the landscape by reducing or removing existing structures (especially linear elements) or creating large open areas.
- Preserve and create landscape elements such as hedgerows and treelines.
- Favour small-scale forest management practices (no clear-cutting).
- Retain deadwood and trees with cavities.
- Avoid the use of pesticides in forests and anti-parasitic drugs for cattle.
- Increase the availability and quality of riparian habitats, including ponds and streams.
- Support ecological measures to increase insect biomass and arthropod diversity within feeding areas.
- Maintain dense riparian vegetation, especially marshes, shrubs and broad-leaved trees.
- Avoid light trespass to bat habitats.

1 Introduction

World-wide, habitat loss, degradation and fragmentation have been identified as major causes of biodiversity loss. Whilst attention focuses on global biodiversity hotspots, such as tropical rain forest and coral reefs, a biodiversity loss continues even in Europe, where much of the landscape is already heavily influenced by human activities. Farming and forestry are by far the largest land-users in Europe and thus their wise use of land is very important in global and national efforts to halt and reverse biodiversity loss. In addition, the development of the built environment and its associated infrastructure, such as the road network, can have a significant impact on biodiversity, not only through direct land-take and road-kills but also through less obvious effects such as light and noise pollution, disturbance and alterations to the local climate.

As everywhere around the globe, bats are a vital component of biodiversity in Europe and have certainly suffered declines in the past, though the absence of data means that we have very little information about past populations. As long-lived, slow-breeding species at the top of the food chain, they are quite vulnerable to environmental change and can recover only slowly from population crashes. In addition, living in large colonies make them unusually vulnerable to both natural disasters and human disturbance, as a substantial proportion of the local population can be found together in one place at certain times of the year.

Until recently, much conservation effort for bats has been focused on their roosting sites, as these are where bats are at their most vulnerable to disturbance or destruction. There is also evidence from studies on artificial roosts that a lack of suitable roosting sites can be a limiting factor for some bat populations, particularly for species with special roosting requirements. EUROBATS has already published guidance documents on the conservation and management of bat roosts in different situations: underground (Mitchell-Jones *et al.* 2007) and overground roosts (Marnell & Presetnik 2010).

However, protecting bat roosts alone is not enough to ensure the conservation of bat populations. Outside the roost, bats need suitable habitats where they can hunt and find sufficient food of the right sort, as well as routes that allow them to travel between roosts and hunting areas. Until the mid-1980s, very little was known about the movement of bats beyond the roost, but this knowledge gap has been changed dramatically by the development of bat detectors, radio-tracking and other technical devices. These research methods have allowed us to follow bats from their roosts, determine how far they fly, and the types of habitats they need for hunting. Our knowledge of the needs and habits of individual bat species is constantly increasing, and we can provide some advice for the conservation and management of their feeding areas.

This guidance, which draws on the latest scientific information, should help foresters, farmers and other land-managers take the needs of bats into account during their operations and thus make a positive contribution to the conservation of these threatened animals. It should also help regulatory authorities ensure that agriculture, forest management regulations and support schemes are designed in such a way as to ensure the conservation of these protected species. As this guidance is intended to cover the entire EUROBATS area, supplementing it with national guidance is highly encouraged. National or regional guidelines can better take local farming and forest management practices into account and ensure that the guidance is locally relevant.

2 Why conserve and manage bat habitats?

The need to conserve bats as a vital component of biodiversity is widely recognized and bats are now legally protected by most of EUROBATS Parties and non-party Range States. Although it has taken time to change, many countries can now report more favourable public attitudes to bats. However, when bat roosts and habitats are formally protected in many European countries and within all EU Member States, real conservation actions rarely extend beyond the roost and its immediate vicinity.

Bats forage in a wide variety of habitats, both natural and managed, but some are clearly more important than others. In many cases, strictly protecting all their feeding areas, which can include farmlands, orchards, forest plantations and residential areas, is not a feasible option. Although bats do benefit from the legal protection of important natural habitats, such as national parks and monuments, other mechanisms should be implemented to preserve a network of feeding areas and commuting routes outside protected areas.

As major predators of insects and other invertebrates, the health of our bat populations is a good indicator of the health of our environment. Their value as an indicator of biodiversity is already recognised and bats may soon be adopted as an indicator group at the EU level, based on the prototype Pan-European bat indicator (Haysom *et al.* 2014, Van der Meij *et al.* 2015).

3 What are critical feeding areas and commuting routes?

Though bats use diverse types of biotopes with varying degrees of human impact, some key aspects are common: feeding (foraging) areas around and near maternity roosts are of priority. Such areas should offer a rich supply of prey insects to ensure the survival of bats, and the landscape structure should favour the movements between roosts and these areas (commuting).

Feeding areas near maternity colonies are of foremost importance for habitat management, as the energy demand of pregnant and lactating females is highest. Good nutritional condition of the female enhances the fetal development and later the growth of young.

Fledgings also need productive feeding areas within a few hundred meters around their roosting site to survive their first crucial months. Whereas female bats may travel several kilometres to forage, data collection on the distances and spatial preferences often requires long-term and costly studies.

Research into habitat preferences has mainly been conducted using radio-tracking, as this technique allows constant following of the bat and therefore delivers relatively precise data on the habitat choice. Also, acoustic monitoring with bat detectors and automated call recorders (passive monitoring detectors) renders data on bat activity at certain spots or along a route. These methods differ in the resulting data type, costs and labour demands (Kunz & Parsons 2009). Chapter 6 of this guidance summarises available results of studies on European bats, including habitat preferences and distances travelled between the roost and the feeding areas. Radio-tracking studies have been prioritised in the literature search, but also information from studies using bat detectors and other methods have been included.

As bat species differ in their choice of feeding areas, there should be good knowledge of the species inhabiting the area and their local ecology. Conservation and management of important feeding areas and commuting routes should be based on adequate information and therefore any land use project likely to affect bats, their roosts and feeding environment should include a bat survey and analysis of the projects' potential effects on bats. The scale of survey chosen should be guided by the probability of bats inhabiting the area and the impacts of the development or management action. Good practice guidelines on bat surveys are available (*e.g.* Collins 2016). Any development near known bat roosts should be preceded by a bat survey. The aim of a bat survey is to find out the species occurring in the area and their roost sites, feeding areas and commuting routes from roosts to these areas.

Results from different monitoring schemes for bats can also provide valuable information for the management and conservation of bat habitats. Since the output of long-term monitoring programmes usually draws from a larger dataset consisting of a lengthy period of observations, they might have more power in describing the bat populations of certain areas than surveys, based on only one field season.

The value of an area for bats may be estimated using species composition – rare or sensitive species being more valuable than common and/or generalists – and numbers of individuals feeding or roosting in the area.

As bats orientate and locate their prey using echolocation, the structure of the landscape can either facilitate the movements of bats or make it very demanding or dangerous for them. Bats with strong, low frequency echolocation pulses use open space when moving or hunting, whereas species with lower intensity calls rely on acoustical cues of the landscape. This means they usually follow structures such as hedgerows and other tree lines, fences or edges of forest patches. For these species, linear and other landscape structures are an important part of their habitat without which they may have difficulties commuting from the roost to the foraging area. The loss of small-scale landscape structures arising from major changes to rural landscapes in recent decades, as well as forestry practices favouring large, open clear-cuts, affect bat species which use linear landscape elements and prefer a fine-scaled environment.

Several bat species are known to migrate from their summer areas to other sites to hibernate. As these species fly great distances (up to 2,000 km in Europe) they need either to stop to feed at suitable areas en route or feed during their flight. Whether they do one or the other is still to be answered by studies on bat migration ecology and physiology. In any case, feeding areas along migration routes also need to be taken into consideration which poses challenges to surveys.

Bats in general and especially reproducing females favour biotopes with high insect production, such as woodlands near water bodies, broadleaf forests, parks and orchards. Many bat species, however, use a variety of feeding areas, some species being more specialised in certain biotopes, including urban habitats. Data on feeding areas favoured by different European bat species are summarised in Chapter 6.

4 How to protect important feeding habitats?

The quality of habitats for bats can be enhanced in many ways. As a general guideline, the maintenance and creation of small scale structures is encouraged and the creation of large open areas or the interruption and fragmentation of existing linear structures should be avoided. Many bats favour linear structures, edges and other elements they can follow, and their roosts and feeding habitats should be connected by such structures.

Changes in the landscape structure, including the fragmentation and loss of important habitats, the loss of natural or semi-natural patchiness, and the homogenous structure of managed areas (agricultural *etc.*) may affect bats. It should be noted that some management practices may create feeding areas but destroy roosts, for example forestry practices where old trees are removed but only small open areas created. Therefore bats, as any other part of biota, benefit from a strategy for the whole landscape. More information on management practices favouring bats is also given in the publication "Habitat Management for Bats" (Entwistle *et al.* 2001). In some cases, international cooperation is required to conserve important bat habitats across adjacent national boundaries.

4.1. Forest management practices

Many European bat species use forests both for roosting and foraging. Diverse types of roosts are available in woodlands, depending on the age and structure of a forest stand. Woodpecker holes and cavities as well as hollow branches are easier to spot for a surveyor, whereas roosts under loose bark are more difficult to detect. As woodland bats tend to use many summer roosts, a high number of trees with cavities must be available to sustain a network of roosts. In general, forest stands with a high ratio of old trees and deadwood provide a perfect choice of roosts (Meschede & Heller 2000, Boye & Dietz 2005, Russo *et al.* 2016).

Forests offer important feeding opportunities for bats, which often prefer foraging in forests with a semi-open structure. Typically, very young forests or patches of dense sapling stage are not favoured habitats for bats, similarly, monocultures are not optimal foraging habitats. Bats prefer to forage in mature forests with small open patches created by fallen trees or small-scale forest management actions. Also, narrow paths, streams and other small open structures in the landscape provide good feeding areas and commuting routes.

As bat species differ in their morphology and echolocation call characteristics, they also use different foraging strategies often referred to as gleaning, aerial hawking and perch hunting. These strategies affect the habitat selection of the bats – aerial hawkers typically exploit open areas in forests or above the canopy whereas gleaners, which often pick insects off foliage, rely more on the understorey or strata near the canopy (Law *et al.* 2016).

In many situations, clearings resulted from forest management practices are too wide for bats to cross. Multi-aged stands and small clearings would better ensure the survival of bats in the forest area. Connectivity between forest areas should also be taken into consideration after forest operations, because fragmented habitats without interconnecting structures may lose the value for bats. Tree lines or groups of trees can be used to link the patches.

4.2. Water bodies, wetlands, river valleys

Bodies of water are key habitat elements for all European bat species, because they offer both drinking sites (see Korine *et al.* 2016) and feeding areas.

Static or slow running waters are crutial for many insectivorous bat species within the EUROBATS area, most notably for *Myotis capaccinii*, *M. dasycneme* and *M. daubentonii* which spend considerable time trawling insects from the water surface. *Nyctalus* species also frequently hunt over water, although at a greater height. Insect-rich habitats, such as water bodies and associated woodlands may be vital for lactating females, as was demonstrated in a study on *Vespertilio murinus* (Safi *et al*. 2007). *Pipistrellus* spp. and many other species utilise tree stands along water ways and riverine forests. Desert-dwelling species such as *Otonycteris hemprichii* may be particularly dependent on water sources within their home range. In drier habitats, the availability of water in feeding areas is important for an entire range of species (Russo & Jones 2003, Almenar *et al*. 2006, Biscardi *et al*. 2007, Rainho 2007, Lisón & Calvo 2011, Salsamendi *et al*. 2012).

Water quality may be a significant factor for bats, as hunting activity over polluted water bodies can be reduced (Kokurewicz 1995, Vaughan *et al*. 1997, Langton *et al*. 2010, Aughney *et al.* 2012). The type and extent of riparian vegetation may also be significant. For example, the importance of an open, vegetation-free water body is obvious for the surface trawling *Myotis* species. A better understanding of the role of these elements in the ecology of bat species is needed.

4.3. Bats in the agricultural landscape

Agriculture dominates the landscape through Europe, occupying around a half of the territory of the EU (Stoate *et al.* 2009). For this reason, many bat species can be found in agricultural landscapes, and the species diversity may depend on traditional farming systems (Williams-Guillén *et al.* 2016), for example *Rhinolophus* spp. in dehesas/montados and semi-natural olive groves (Goiti *et al.* 2008). Although some traditional agriculture remains, during the past sixty years there have been huge changes in farming throughout Western Europe. A large-scale switch to intensive land-management has been defined by conversion of natural habitats into crops or pasture, increased mechanisation, larger field sizes, greater use of synthetic fertilizers and pesticides, widespread drainage, new crop species and varieties, extended cropping periods and a change from mixed farming systems to landscapes dominated by a single use such as intensive grass, arable or, in the Mediterranean, olive groves, citrus orchards or eucalypts plantations. Agricultural intensification has been linked to the severe decline observed in many species of farmland wildlife, and although there is a paucity of data during the time of maximum change, the severe declines that bats experienced in the latter half of the twentieth century across Western Europe have been attributed in part to its impact, both directly and through the reduction of prey species (Hutson *et al.* 2001, Williams-Guillén *et al.* 2016). For example, in the UK, semi-natural unimproved grasslands now occupy around 1% of their former area. This may explain the extreme rarity of *P. austriacus*, for which unimproved grassland and marshland are preferred foraging habitats (Razgour *et al.* 2013). In an experiment to simulate some of the potential impacts of intensification, Pocock & Jennings (2008) found bat activity significantly decreased after vanishing of hedgerows and showed that most taxa were highly sensitive to boundary loss. Pressures on bats in agricultural landscapes are likely to increase, as management becomes more intensive in Eastern Europe, where the sector responds to increased demands for food and biofuel.

The value of farmland in the broadest sense as foraging habitat for bats depends on the balance of green veining (non-cropped habitat such as hedgerow, woodland, *etc.*) to openness (cropped land, intensive pasture/silage *etc.*), and the insect density, which in turn is influenced by management. Traditional orchards or olive groves, semi-natural pasture and hay meadow systems can be valuable for many species including threatened or locally rare ones. Downs & Sanderson (2010) found that the activity of *E. serotinus*, *P. pipistrellus* and *Myotis* spp. was significantly higher in the presence of cattle. Intensively managed grassland or crop fields may only be of limited value for foraging, used at certain times of the year, by a smaller number of more common species. Fragmented landscapes, where connective features such as hedgerows and tree lines were removed, may isolate roosts from potential feeding areas.

Agri-environment schemes (AES), incentive payments to farmers to restore and enhance farmland habitats for its biodiversity and cultural value, are now obligatory in the EU and common across Europe. To date, few schemes have targeted bats specifically, a well-known example being the Greater Horseshoe Bat Project which operated in southwest England between 1998 and 2003 (see Case Study 1). However, many measures that have been prescribed for other species or for wildlife generally, are likely to help bats and their invertebrate prey. Examples include re-instating and restoring hedgerows, planting trees and native woodlands, buffering watercourses from inputs of nutrients and sediment, installing ponds, maintaining and restoring old orchards, reducing fertilizer and pesticide inputs and altering cutting or grazing regimes to increase the structural and species diversity of grassland. There is ongoing debate about how successful AES have been in benefiting wildlife populations, with different responses among species and to date few studies of bats. In Scotland, nocturnal insect density and bat activity were compared between 18 pairs of farms under AES or conventional management (Fuentes-Montemayor *et al.* 2011). The measures included field edge and hedgerow management, development of species-rich pastures and water edge management. Insect densities and bat activity were significantly lower on AES farms. The study showed that the landscape surrounding the farms influenced bat activity and concluded that to benefit bats AE schemes should influence management at landscape-scale, particularly the establishment and management of woodland in agricultural areas. In contrast, MacDonald *et al*. (2012) compared bat activity between AES and regular pastures and found a non-significant increase of bat activity on AES parcels.

There is some evidence that organic farming benefits bats, though it is uncertain whether this is due to the absence of pesticides or to the presence of higher quality non-crop habitats. Wickramasinghe *et al*. (2003) compared organic and conventional farms, finding more bat activity and more foraging activity over organic farms. In a multi-taxa multi-site study Fuller *et al*. (2005) observed higher bat activity and bat species richness on organic than conventional farms.

4.4. Urban areas, parks

The value of urban landscapes for wildlife is frequently underestimated, and consequently provision for species such as bats is often overlooked. However, many European bat species have adapted to live near humans. Roosting in buildings and akin man-made structures allows these species to exploit urban landscapes wherever their essential foraging and commuting requirements are met.

Most towns and cities have areas of cultivated and semi-natural vegetation that may provide foraging opportunities, such as gardens and parks, alleys, rivers, canals and lakes, railway embankments, road verges and areas of waste-ground. However, while there are many casual observations of bats making use of such places, there is a lack of formal academic research on foraging activity within built landscapes in Europe. In a large Czech city, Gaisler *et al.* (1998) found the highest bat activity along the river in low-density residential areas and lowest around high-density residential areas and in the city centre.

New developments can put pressure on urban bat populations where foraging habitat is lost, either through conversion to built structures or because commuting routes between roosts and foraging grounds have been severed. Hale *et al.* (2012) found that *P. pipistrellus* studied at urban ponds in the UK were negatively affected by increasing densities of buildings once buildings exceeded 60 % of land area, but that the presence of tree networks could buffer the negative effects of urbanisation to a degree. Bat populations that live and forage in built environments may experience pressure due to the effects of artificial lighting, traffic noise and pollution both directly and through the response of their invertebrate prey. Gerell & Gerell Lundberg (1993) found that a population of *P. pipistrellus* in an industrialised area of Sweden exhibited declining trend when a rural one was stable, likely due to differences in the quality of their feeding areas.

New developments also bring the opportunity to improve urban landscapes for bats and other wildlife by planning in green infrastructure at the earliest stage of development to ensure that there is adequate foraging habitat (*i.e.* not just the preservation of roosts), and connectivity to important feeding areas like parks, urban woodlands, ponds and lakes. Planning obligations to ensure sufficient drainage from hard landscape can be exploited to create vegetated opportunities for wildlife (*e.g.* ponds, lakes, swales). Pearce & Walters (2012) found that activity of urban bats was significantly higher above diversely vegetated green roofs than above normal buildings. Innovative solutions to address artificial lighting and traffic issues are the subject of on-going research to inform future conservation measures. Guidelines for planners and landscape architects are available (see Voigt *et al.* 2018).

4.5. Linear elements and routes to roosts

Commuting routes

In landscapes untouched by human management or development, habitats are often characterised by high connectivity, these permeable landscapes allow bat species to access feeding areas with relative ease and bats have evolved to exploit the heterogeneous nature of these natural landscapes. When stochastic natural events may cause the destruction of suitable feeding areas, there are usually alternative sites that could compensate this loss while disturbed habitats are restoring. The conversion of wild landscapes for agriculture, felling of woodlands, increasing levels of urbanisation and the intensification of transport infra-structure disrupt this natural environment. The resulting habitat fragmentation can isolate suitable feeding areas from roosting sites. In many modern landscapes bats depend on these linear features, employing them both as commuting routes and feeding areas.

Figure 4.1. Unpaved road in a floodplain poplar forest in Georgia – an important commuting route and feeding area for R. ferrumequinum, R. hipposideros, M. nattereri, M. emarginatus, M. daubentonii, M. bechsteinii, M. brandtii, M. davidii, B. barbastellus, E. serotinus, P. pygmaeus, P. pipistrellus and P. kuhlii. © Suren Gazaryan

The level of dependency on commuting corridors varies considerably between bat species. Some species, such as *Nyctalus* spp. are capable to detect prey and potential predators from longer distances and adapted to flying at height in open spaces. These species can easily cross open landscapes. *R. hipposideros*, a species with high frequency echolocation calls that rapidly attenuate, severely limiting its ability to echolocate objects more than a few metres away, is at the other end of the scale. This species is highly dependent on vegetative cover and the removal of linear landscape features can hinder the opportunity to forage in isolated woodlands. There is a gradient of dependency on commuting routes, but usually smaller bats are more reliant on these features than larger ones. However, this observation has caveats as larger species with higher frequency echolocations calls are also more likely to require continuous vegetative cover to access their feeding areas, as in the case of *R. ferrumequinum.*

The type of structures used as commuting routes varies considerably depending on local landscape features. In the pastoral habitats these are typically hedgerows, tree-lines and riparian corridors. In landscapes devoid of these features fence lines, dry stone walls, natural rock formations or even underground passages can fulfil the role, however, these lack the same 'en route' foraging opportunities associated with vegetation.

The importance of these features is higher near roosts because they protect bats from light trespass during emergence in twilight (see Voigt *et al.* 2018).

Frey-Ehrenbold *et al*. (2013) demonstrated that bat activity and species richness were higher around linear landscape features than in open agricultural landscapes, and that more animals were present in parcels that were "tied into" the network of linear features. Boughey *et al*. (2011) showed that activity of *P. pipistrellus* was significantly higher along hedgerow features where trees were present and nearer to a woodland. Hence, they recommended that AE schemes should promote planting and retention of hedgerow trees for bats.

4.6. Strategic legal tools

Farming and forest management remain crucial for land use and the management of natural resources in the EU's rural areas, and as a platform for economic diversification in rural communities.

The European Agricultural Guidance and Guarantee Fund (EAGGF), set up by Regulation No 25 of 1962 on the financing of the common agricultural policy (CAP, as last amended by Regulation (EEC) No 728/70) consumes a large part of the general budget of the European Union.

Through the Rural Development Programme, it supports rural development and the improvement of agricultural structures, such as the Agri-environmental measures and the optimal utilisation of forests.

Agri-environmental Schemes reward farmers for environmentally-sensitive land management. The agri-environment schemes are considered crucial in relation to biodiversity and sustainability.

Some examples that can be undertaken by Member states in favour of bat critical feeding areas:

- Agri-environmental schemes: management of unimproved grassland, of ponds, of hedges, conservation of permanent pastures along rivers or permanent grassland along forests;
- Optimal utilisation of forests: conservation of broadleaved forest edges, conservation of old trees and cavity trees in private and public forests.

The paying agencies make payments to beneficiaries in accordance with the Community rules.

The **conditionality** of these payments to farmers' are in compliance with basic environmental and animal welfare standards ("cross-compliance") strenghten the impact of the CAP. Farmers may have their direct payment reduced, or in extreme cases, completely cancelled, if they do not respect a set of Good Agricultural and Environmental Conditions (GAEC) and Statutory Management Requirements which are linked to 18 EU Directives and Regulations relating among others to the Habitat Directive.

Some examples of GAEC that can be chosen by Member states in favour of bat critical feeding areas: conservation of topographic elements such as hedges, isolated trees, ponds, public rights of way.

LIFE is the EU's financial instrument supporting environmental and nature conservation projects throughout the EU, as well as in some candidate, acceding and neighbouring countries. Since 1992, LIFE has co-financed 3,115 projects, contributing approximately € 2 billion to the protection of the environment.

Some examples of LIFE projects in favour of bat critical feeding areas:

CHIROFRSUD: The project partly aimed to study the foraging habitats and diet of 3 bat species and to elaboration of management recommendations for the foraging habitats (Némoz & Brisorgueil 2008).

CHIROMED: LIFE project in south-eastern France focussed on *R. ferrumequinum* and *M. emarginatus* with some actions to improve foraging habitats (plantation of hedgerows linking roosts to foraging habitats, enhancement of good practices in the use of anti-parasitic drugs for livestock, operational mitigation to stop/reduce bat mortality in some dangerous road sections).

The Greater Horseshoe Bat in Upper Palatinate, the LIFE project in southern Germany aimed at the optimisation of habitats and public awareness (see Case Study 4 for details).

Other tools can enhance the efficiency of cross-border cooperation in the field of rural development (**Interreg, Instrument for Pre-Accession Assistance**). It may also concern the protection of the bat fauna.

4.7. Summary of actions favouring and harming bats

Though bat species differ in their habitat preferences, there are some actions that typically favour or imperil all bat species. Similarly, some management practices are usually harmful for bats (Table 1). For instance, illumination of roosts, feeding areas and commuting routes shall be avoided (Voigt *et al.* 2018).

Action	Positive impact	Negative impact	Remarks	Mitigation measures
Light installations		x	See Voigt *et al.* 2018	Depending on impact assesments
Wind energy development		x	See Rodrigues *et al.* 2015	See above
Residential development		x	Depending on the density	See above
Road construction		x		See above
Forest operations: clear cutting		x		Retain treelines and old trees
Forest operations: small patch cutting	x		In a monotonous woodland only	Retain old trees
Deadwood removal		x		Alternative roosts provided
Removal of dying trees		x		Alternative roosts provided
Use of pesticides in silviculture and agriculture		x		Avoidance
Use of herbicides		x		Avoidance
Creation of new hedgerows	x			
Expansion/creation of field margins and dikes	x			
Creation and maintenance of ponds	x			
Creation and maintenance of riparian areas	x			
Maintenance of a diversified undergrowth	x			
Preservation of old buildings	x		Water mills, barns, bridges, *etc.*	

Table 1. Favourable and imperilling management actions withing feeding areas and commuting routes for bats.

5 Successful cases of habitat management for bats

As resources are limited, evidence-based conservation would be an optimal way of ensuring the favourable future of species. Well reported cases of successful habitat management for bats can help in the planning of conservation and management by providing important background knowledge and best practices. However, there are reported cases available where the outcomes of the actions have been monitored.

Case Study 1. Habitat management for the Greater Horseshoe Bat *(Rhinolophus ferrumequinum)* in Devon, Cornwall and Somerset

R. ferrumequinum has a restricted distribution in England, with a small number of widely spaced and isolated populations. It is believed to have undergone a significant population crash and reduction in range in the first half of the 20th century and most of the remaining populations are quite small and fragile. The species was one of the first to be protected by specific wildlife legislation in 1975.

Up till the 1990s, conservation action for the species focused largely on identifying and securing the remaining maternity and hibernation sites, many of which were threatened by neglect, decay or inappropriate development of various sorts. Much of significant roosts, both maternity and hibernation, are now well-protected and managed.

Once most of the roosts had been secured, attention turned to the other major resource needed by the bats – feeding areas with appropriate food resources. To make progress with this conservation work, several important pieces of information were needed:

- How far from the roosts the bats flew on their nightly foraging trips,
- Which habitats they hunted over and whether they followed linear landscape features when commuting,
- What insect prey they preferred at various times of the year.

Attention initially focused on the maternity roosts, as these contain the largest concentrations of bats with the highest energy demands, though some work has also been done on foraging habits around hibernation sites.

Development of habitat management recommendations

Initial information about the foraging habits of the species came from research work, particularly that carried out by Gareth Jones and his colleagues at Bristol University (Jones & Morton 1992, Jones *et al.* 1995). Radio-tracking provided data on the foraging habits of the bats, including the differences between adults and juveniles. Key findings for a habitat management project were:

- For the maternity roosts studied, most foraging activity was within 3 – 4 km of the roost. Juveniles initially foraged with-

in 1 km of the roost before later extending their foraging range.
- The most important foraging habitats were cattle-grazed pasture and mixed deciduous woodland. Juveniles were very dependent on pasture while they learnt to hunt.
- Bats commuted along linear features, particularly hedgelines, and foraged at the interface between grazed pasture and woodland.

This work on foraging behaviour was then supplemented by detailed dietary analyses (Ransome 1996, 1997) to determine the key prey items for both adults and juveniles while occupying the maternity sites. From these data, and knowledge of the ecology of the prey species, critical feeding habitats could be identified, leading to detailed habitat and landscape management recommendations below.

Pasture

Retain existing grazed permanent pasture and create further areas of botanically diverse pasture to promote high densities of insect prey. Ideally, 50 % of the land within a 4 km radius around each maternity roost should be pasture.

Maintain pasture as small fields separated by substantial hedges containing larger trees, minimise insecticide use against cutworms, wireworms and leatherjackets to avoid disrupting insect life cycles.

Grazing regimes should be favourable for insects and keep pasture in good condition. Annual stocking rates for unimproved pasture should average about 0.5 cattle or 4 sheep per ha but could be increased to 1 to 3 cattle (5 to 16 sheep) per ha for short periods, providing this does not damage the pasture. These higher stocking densities should be maintained within 1 km of maternity roosts during July and August, with stock rotated between fields rather than ranched throughout the farm to help control parasites.

Manage stock without the use of wormers based on Avermectin compounds (*e.g.* Ivermectin) as such chemicals remain active in the dung, preventing colonisation by dung beetles.

Hedges

Maintain all hedges, managing them to create tall, bushy structures, ideally with a broad base of between 3 and 6 m to provide sheltered flight paths for bats. Leave mature trees and encourage young saplings to grow on into hedgerow trees to provide shelter and feeding perches.

Create new hedgerows and tree lines across large open areas of permanent pasture, linking with existing hedges and woodland blocks to improve the network of flight paths and increase the area of pasture available to foraging bats. New hedges should be broad (3–6 m across) with an average height of 3 m. Hedgerow trees should be dotted along the length of the hedge.

Leave uncultivated arable field margins adjacent to hedgerows to provide insect food for the bats.

Woodland, parkland and old orchards

Retain existing mature ancient semi-natural deciduous woodland and create further blocks of deciduous woodland, shelter belts or small woods adjacent to grazed pasture. Ideally, up to about 40% of the land within a 4 km radius of each maternity roost should be deciduous woodland to support good populations of moths and provide sheltered areas for foraging bats. Areas of high conservation value, such as unimproved grassland, should not be converted to woodland.

Woodlands should contain grassy rides and glades, managed without insecticides. Glades should be at least 10 to 15 m across to promote use by foraging bats. Coppice compartments should be small, to provide the maximum woodland edge habitat.

Promote the development of a parkland landscape by planting additional standard trees in pasture areas (but do not plant trees or shrubs on unimproved or semi-improved pasture without seeking conservation advice). Newly planted trees should be adequately guarded against stock damage and managed to grow well developed crowns.

Old trees ('veteran trees') are particularly valuable to a wide range of wildlife, including bats. Try to retain these wherever possible, seeking specialist advice where necessary.

Old orchards, with rows of mature fruit trees over a grazed understorey, can be valuable hunting areas for bats, provided insecticide use is restricted.

Marshy and aquatic habitats

Retain existing and create new areas of marshy and aquatic habitats, such as ponds, to support good populations of craneflies and other insects. Again, avoid areas of high conservation value for creating ponds.

Delivery of habitat and landscape improvements

The main way in which habitat improvements on a large scale can be delivered is through government and EU-funded agri-environment schemes. These voluntary schemes support farmers in delivering environmental benefits, usually through long-term agreements with annual payments. Most schemes are targeted at particular areas or habitat types and involve applicants selecting from a series of options to deliver a farm-specific package of environmental benefits.

During the course of the work, two agri-environmental schemes were available. The higher-level tier of ESS is comparable to CSS and is the main one of interest.

Scheme	Period available	Characteristics
Countryside Stewardship (CSS)	1991–2005	Competitive scheme targeted at high nature conservation value land. Many options and combinations of options.
Environmental Stewardship (ESS)	2005–present	Two-level scheme. Entry level, available to all, provides low-cost modest environmental benefits. Higher level, competitive and targeted, provides greater environmental benefits at higher cost.

By 1998, sufficient information was available from the research work to identify options available in Countryside Stewardship that would deliver benefits for *R. ferrumequinum* and a project officer was appointed to take the work forwards. A leaflet was produced summarising the conservation requirements of this bat, with a more detailed supplement available for landowners interested in committing to a CSS agreement. The role of the project officer was to improve the understanding of the needs of the bats within the target area and identify and visit farmers with land in the roost sustenance zone (within 4 km of the roost) and persuade them to enter stewardship agreements with options that would benefit the bats.

Between 1998 and 2003, when the project ended, the project officers visited and provided advice to 163 landowners managing approximately 13,211 ha of land in bat feeding areas around key maternity and hibernation roost sites in Devon, Cornwall and Somerset. After some negotiations, 46 of these farms, covering 4,191 ha entered Countryside Stewardship Scheme agreements. In addition, extensive support was given to partner organisations to improve their management advice and agreements for the bats, resulting in a further 31 bat-related management agreements covering approximately 2,345 ha.

Options used within the agreements included the following:

- improving important feeding areas by reverting arable land to grazed grassland;
- management of permanent pasture and hay meadows with targeted grazing regimes to ensure plentiful supplies of key prey species for the bats;
- creation of wide grassy arable field margins alongside hedgerows and woodland edges;
- maintenance and improvement of bat commuting routes through the restoration of hedgerows (laying, coppicing and replanting gaps) and new planting of hedge boundaries, parkland trees and tree lines.

Through the work of the project, 80 km of hedgerow located within the roost sustenance zones was designated for replanting or restoring under the CSS. In addition, nearly 400 ha of grassland was brought under specialised management for the bats.

The project has provided management advice, and assisted with CSS applications, on a number of organic, in-conversion or extensively managed farms. An example is Riverford Farm which is an organic dairy enterprise operating in South Devon within the Buckfastleigh roost sustenance zone. They entered the CSS, following advice from English Nature, with specific measures to benefit the bats. During 2001, a marketing initiative was developed with Riverford Farm, whereby they featured information about the bats and English Nature on their milk cartons. The simple message on the carton was used to inform consumers about the link between extensive agriculture and the provision of insect prey for the bats. Approximately 7,000 cartons a week are sold across south-west England and in Hampshire and London.

Figure 5.1. Carton with information for customers. © English Nature

This initiative brought the project and English Nature to a new audience both within, and beyond, the project target area at no cost (LONGLEY 2003).

Since 2005, when Environmental Stewardship was introduced, work to deliver environmental benefits in the roost sustenance zones has been incorporated into the work of the scheme advisors, rather than requiring a dedicated project officer. As CSS agreements reach the end of their life (usually 10 years), farmers will be offered new ESS, higher level agreements to continue delivering environmental benefits for the bats. By 2008 almost 9,000 ha of land in the target areas was in an agri-environment scheme agreement.

Measuring success

The ultimate measure of success for this land management work is an improvement in the status of *R. ferrumequinum*. Colony counts from the National Bat Monitoring Programme, run by the Bat Conservation Trust, show that the species is currently increasing in numbers. GB-level trends for greater horseshoe bat from the Hibernation Survey shows a statistically significant increase since the baseline year figure. However, at a country level some differences can be seen. Although the greater horseshoe bat population is increasing significantly in England, the trend in Wales is not yet significant; further research is needed to explore the reasons behind this difference between countries.

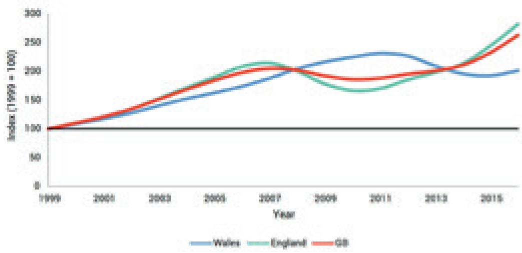

Figure 5.2. Population trend of R. ferrumequinum in Wales, England and Great Britain. © BCT

Unfortunately, it is not currently possible to determine whether colonies where habitat restoration work has been focussed are increasing faster than other colonies because of small sample sizes and the fact that all colonies have benefitted to varying extents from agri-environment schemes.

Case Study 2. Habitat Enhancement for the Greater Horseshoe Bat *(Rhinolophus ferrumequinum)* in Dorset

Background

This project was based around a maternity colony of *R. ferrumequinum* in Dorset, south-west England. Discovered in the 1950s, the colony occupied a large disused building on the edge of the flood plain of the River Stour and at the time was one of a handful of roosts for this species known in the UK. In 1994 the building was purchased by The Vincent Wildlife Trust and established as a nature reserve for the bats. In the following years considerable work was undertaken to enhance the building for the bats and by 2002 the colony had grown from about 60 to some 140 animals. With the building in good condition, it was recognised that the foraging habitat surrounding the roost was equally important and this was something that had to be addressed, especially as the landscape features were considered to be less than optimal.

Assessing the habitat

Although it was recognised that ideally work should be undertaken at a 4 km radius of the roost, for a detailed assessment this area was too large and it was decided that greatest impact could to target work within 2 km of the roost. Within this area the habitat was mapped onto a Geographical Information System with habitat data being collected using aerial photographs and field-based surveys. The intention being to identify the location of preferred foraging habitats in relation to the roost and to assess how well these areas were connected to the roost by suitable landscape features.

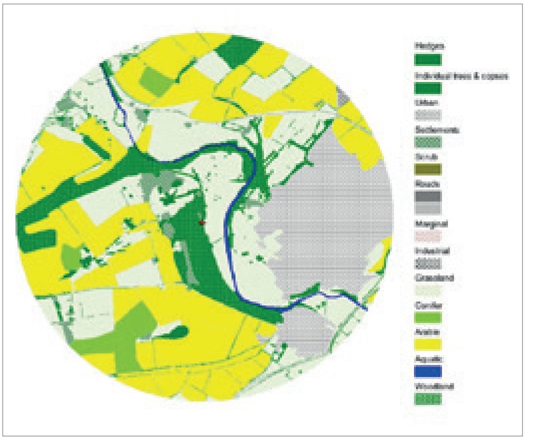

Figure 5.3. Habitat mapped in a two kilometre radius of the roost. © The Vincent Wildlife Trust

The majority of the habitat surround the roost consisted of large arable fields, many of which had been enlarged by removing the traditional hedgerows. These accounted for 30 % of land area within a 2 km radius of the roost. Grassland, much of which had been improved, accounted for 27 % and woodland 19 %. To the east of the roost is a provisional town occupied 14 % of the available land area. The habitat in the floodplain with its riparian woodland and grazed pasture provided the most obvious local feeding areas. However, potential feeding areas to the west and north of the reserve were effectively isolated from the bats by large open arable fields that had been fenced rather than having hedgerows. To reduce the degree of habitat fragmentation in the landscape surrounding the roost nine areas were identified as requiring habitat enhancement work. This work included the planning of new hedgerows, gapping up of existing hedgerows that had become derelict and the planting of a tree line.

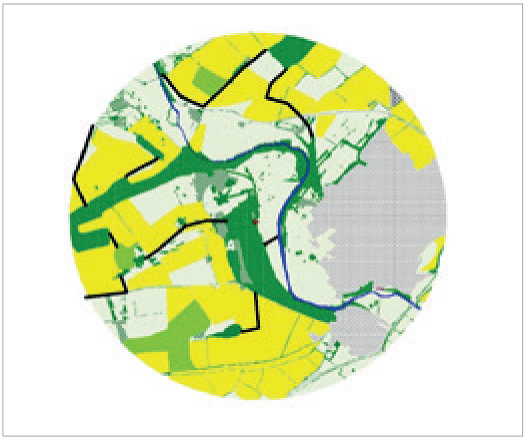

Figure 5.4. Areas identified for re-instatement of hedgerows shown in black. © The Vincent Wildlife Trust

Local land owners were approached for permission to carry out the work and in some cases compensation was agreed with them to off-set the loss of agricultural land. During early 2003 some 2 km of new habitat features were planted around the roost.

Figure 5.5. New hedgerow being planted. © H. Schofield

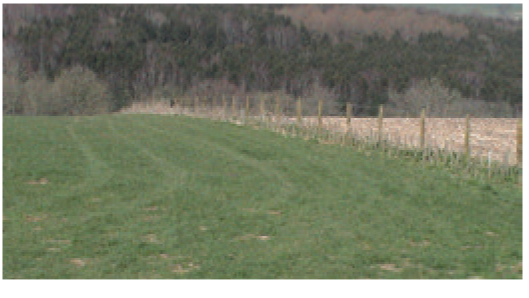

Figure 5.6. Planting completed on a new hedgerow. © H. Schofield

Conclusion

In the ten years since the habitat enhancement scheme the numbers of bats using the roost has increased to 230 animals. The hedgerows have matured and been allowed to grow bushy. Radio-telemetry studies during 2009 and 2010 of the bats have shown that they are now commuting along some of the new hederows and accessing feeding areas that would previously required them flying across open landscape.

Figure 5.7 The effect of planting a dark corridoor leading from the roost. © H. Schofield, C. Morris

Case Study 3. Habitat enhancement for the Barbastelle bat *(Barbastella barbastellus)* in the West Weald (UK)

Background

The West Weald is an area of south-east England in the counties of West Sussex and Hampshire, characterised by undulating landscape containing a mixture of farmsteads, ancient woodland and heathland. It is an important area of the UK for the woodland bat species, including the western barbastelle. A colony of this species was discovered in an extensive area of ancient woodland in 1997 and a subsequent radio-telemetry study of the colony was conducted over 1998/9. In addition to identifying and characterising roost trees and feeding areas, the study highlighted the importance of linear vegetative landscape features with a 5 km radius of the woodland. These served as commuting route for the colony enabling them to remain under cover on route to their feeding areas (see Greenaway 2004).

Assessing the habitat

Field surveys were undertaken of the commuting routes used by the barbastelles to assess the condition of the linear features and determine whether there was a need to undertake habitat enhancement work.

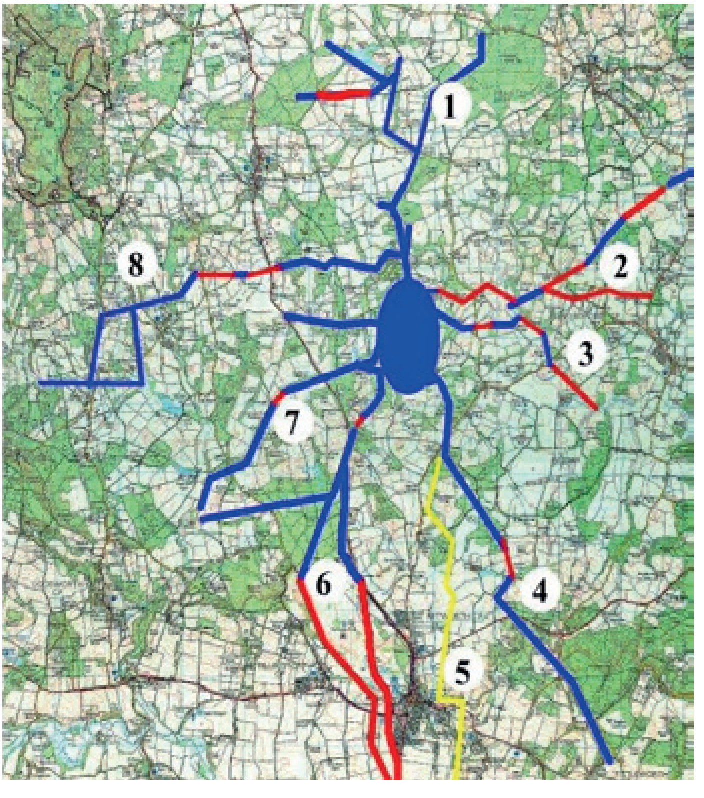

Figure 5.8. Identified flightlines of Ebernoe barbastelles as of 1998: good (blue), unsuitable (red) and abandoned historical routes (yellow) (from Greenaway 2004).

An initial planting scheme was undertaken to improve the quality of the habitat where the condition assessment had indicated it was unsatisfactory. This involved fencing in areas that may be subject to stock damage and either allowing natural regeneration or planting up the enclosures with native species. These provided the bats with broad corridors to fly along at dusk.

Figure 5.9. One of the enclosures set aside for nature regeneration. © F. Greenaway

Figure 5.10. An area with new planting to strengthen the hedgerow and make the corridor broader. © F. Greenaway

Following the initial radio-telemetry study, the colony was monitored for ten years through an extensive ringing project and colony counts using infra-red video equipment, during this period the medium colony size doubled (from 29 to 64 breeding females), and maximum travelled distance decreased from 7.1 to 5.2 km.

Case Study 4. The Greater Horseshoe Bat *(Rhinolophus ferrumequinum)* in Upper Palatinate (Germany): optimization of habitats and public awareness (LIFE11 NAT/DE/000346)

Background

The only colony of *R. ferrumequinum* in Germany has survived in the Lauterachtal valley and the Hohenfels Training Area (HTA). Silvicultural and nature conservation management of the HTA is the responsibility of the Federal Institute for Real Estate Tasks (Division of the Federal Forest Service). The area has been ceded to the U.S. Army for exclusive military within the scope of NATO. The military training area is for the greater part designated as a Natura 2000 site but has no national protection status. Access by private individuals is strictly prohibited, this prohibition is enforced by the U.S. Army and members of the Federal Forest Service. About half of the area is a large, continuous, unfragmented habitat complex of nationwide significance. It is covered with beech and pine forest communities, it includes calcareous nutrient-poor grasslands and large dry grassland complexes subject to low-intensity land use, especially sheep and goat grazing. The landscape structure and appearance of the

FFH area Lauterachtal is geologically influenced by the White Jurassic and characterized by rock formations and dolomite hilltops. Both the plateaus and valley sides are strongly karstified and permeable to water.

For about 20 years, the Landschaftspflegeverband (a landscape management association) Amberg-Sulzbach e.V. have taken management action together with a migrating shepherd and local landscape managers to preserve the above-mentioned special landscape features of Juniper heathlands and calcareous nutrient-poor grasslands.

The maternity roost of *R. ferrumequinum* is situated in an old half-timbered barn of a former agricultural estate. To protect the colony, this estate was bought by governmental and private nature conservation organisations several years before the project was launched, then renovated with funds from the economic stimulus package II to prevent it from collapsing. Action has also been undertaken to save the colony from extinction by increasing the availability of roosts and favorable foraging habitats.

The goal of the LIFE project was to implement immediate protective mechanism for the target species as well as to achieve a high socio-economic effect. This has been successful to date. For instance, setting up a grazing infrastructure has enabled an agricultural enterprise to expand its economic base and resume livestock farming. This was and is intended to have a signalling effect and encourage other farmers in the vicinity to expand their economic base by practicing low-intensity grazing on further areas. Moreover, the grazing of Red Cattle, an Upper Palatinate cattle breed, helps to safeguard this rare, old livestock breed in the region.

In addition, old fruit varieties of partly statewide significance have been planted. Thus, it was possible to associate the nature conservation aspect with the preservation and use of regionally typical fruit varieties that are adapted to the local conditions.

During the project the following management activities have been devised and undertaken to improve feeding areas and habitats of *R. ferrumequinum*:

- Initiating a low-intensity cattle grazing regime on at least 50 ha for the bottom and sides of the valley;
- Buying/leasing areas to allow the formation of grazing complexes;
- Building a cowshed;
- Buying cattle and building up a project-herd of cattle from offspring;
- Establishing the grazing infrastructure, primarily suitable fences.

Assessing the habitat

Field surveys with radio-telemetry have been undertaken since 1992, when the colony was discovered. Hence, critical feeding areas and commuting routes had already been revealed before the project began. Studies on prey composition and vegetation around the roost were conducted for further monitoring (Wolz 2018).

Increasing insect abundance

Low-intensity-use perennial grassland represents an essential mosaic in the foraging habitat of *R. ferrumequinum*. More than 1,000 beetles can live in a dung heap from cattle reared in a near-natural way. Numerous fly species also develop in dung. The eradicated hoofed animals were replaced by human-bred and reared grazing animals for a long time, at least as dung producers. Pasture feeding was substituted by animal housing with the industrialization of agriculture at the end of the last century. This caused a strong decline in biocenoses that had developed on and with dung. The absence of dung in the landscape has resulted in the immediate disappearance of dung-dependent species and secondary biocenoses, such as numerous bird and bat species, including *R. ferrumequinum*. Thus, the herd of the Red cattle established within the scope of the project creates both: landscape structures suitable for bats and the basic food resource for the target species on a total area of 65 ha.

Figure 5.11. Meadow with a herd of Red cattle in Lauterachtal valley, managed for a high insect productivity. © A. v. Lindeiner

Improving landscape heterogeneity and connectivity

R. ferrumequinum is dependent on diverse landscape structures with a mosaic of different habitats. Such low-intensity-use cultivated landscapes represent the preferred foraging habitat of the species. Greater horseshoe bats use specific flight routes to their foraging habitats based on linear structures such as creek courses, forest edges, hedges or rows of trees. Moreover, trees and hedges provide some protection against detection by predators such as birds of prey and owls. Hence, sparse woodland structures are highly significant landscape features. They allow the networking of potential foraging areas and the extension of the bats' foraging territory. Such networking structures have been created by clearing actions at several sites within the project area. More than 140 fruit trees were planted on meadows and along roads. They are valuable as night bat roosts and provide shadow for the cattle, thus accumulating dung.

Improving roosting opportunities

The habitat conditions for the target species have been continuously optimized in the Bat House (main roost). For instance, a heating dome was installed, a small cellar was insulated and barriers against predators and "troublemakers" such as martens or dormice were installed. Two new bat towers were built in the Lauterachtal valley to ease further range expansion. In addition, they contain information desks for cyclists and hikers, simultaneously offering them shelters. Existing winter roosts were monitored, and their protection strengthened.

The number of winter roosts used by *R. ferrumequinum* increased from nine to 23 caves during the project period.

Public relations activities

The established information center provides the Hohenburg's community with a new tourist attraction and opportunity to offer environmental education to schools and preschools in the vicinity (Figure 5.12.). Several craft businesses in the vicinity were commissioned with tasks within the scope of the construction work, thus resulting in a high degree of affinity of the community to "their" bats.

The market town Hohenburg became much more well-known through the events connected with the LIFE project. This heightened public awareness was confirmed by the increasing number of visitors to the bat house.

Figure 5.12. The Bat House (Das Fledermaushaus) in Hohenburg including the information centre. © R. Leitl

Special control technology now enables the immediate display (via whiteboard) of pictures taken with infrared zoom cameras that are installed around the roosting places of the animals in the building. This provides the possibility of witnessing – immediately and live – the social life of the bats in a unique way. Bat detectors are used to make the bat calls audible when the animals leave their roost in the evening. Interactive boards and an interactive monitor with numerous options, open up new ways of obtaining information on the biology, physiology, behavior and protection of horseshoe bats and other bat species.

Success

A slow continuous increase in the number of adult animals and annually born offspring in the maternity roost in Hohenburg had already been observed prior to the launch of the project. Such maternity roosts include reproducing females as well as young males and females that were born the year before and are not yet involved in reproduction. The population of the Upper-Palatinate maternity roost colony recordable in the winter roosts increased from 15 individuals in 1992 to 63 in the winter of 2010/2011. In all, 21 adult females and 10 juveniles were counted in the maternity roost in July 1992, and 69 adult bats and 30 juveniles were counted in summer 2011 – one year before the LIFE project was launched. The project's aim was to promote the species and to achieve an increase in the number of adult animals to at least 100 individuals by the end of the project period. This goal was markedly surpassed based on 180 individuals counted to date (Figure 5.13).

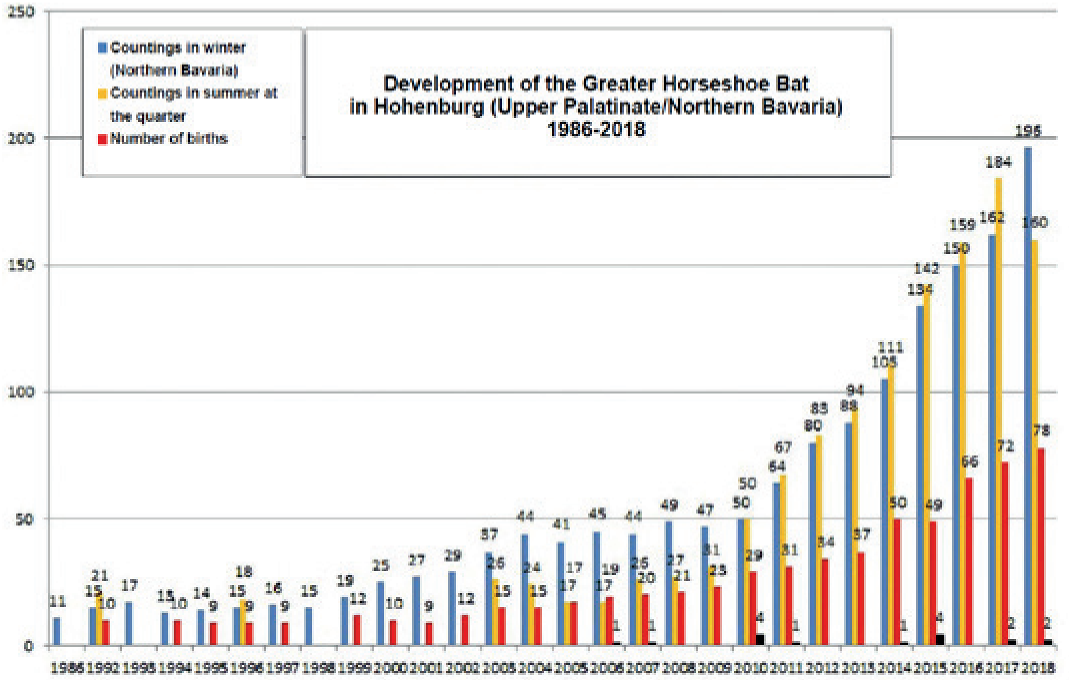

Figure 5.13. Population trends in the colony of R. ferrumequinum in Hohenburg. © LBV

6 Guidance on habitat management for European bat species[1]

Rousettus aegyptiacus (Egyptian fruit bat)

Figure 6.1. Rousettus aegyptiacus with a pup. © Mustafa Sozen

Feeding areas

Flight distance to the feeding area is dependent on the landscape structure, with foraging flights as far as 25 km from the roost. A significant difference in timing of emergence and energy demands was reported between the sexes and between bats with various reproductive status (Korine *et al*. 1994, Korine *et al.* 2004).

In Israel, fruit bats showed a statistically significant preference for foraging near human settlements: the mean distance to the nearest settlement centre was 795 ± 490 m. A feeding area constituted a relatively small site with a median convex hull of 0.052 km^2 per bat. *R. aegyptiacus* usually forage between trees that are close to each other, up to a kilometre away from the roost. However, on rare occasions, larger distances of up to 10 km have been recorded (Tsoar *et al.* 2011).

The main threats to the Egyptian fruit bat are from intentional culling (Korine *et al*. 1999) and from secondary poisoning due to pesticide use in agricultural orchards.

Diet

It is a generalist frugivore feeding on almost all pulpy fruits (Izhaki *et al*. 1995, Korine *et al*. 1996, Korine *et al*. 1998, Korine *et al*. 1999). It may also consume leaves and insects (Barclay *et al*. 2006).

Critical feeding areas

Forests and plantations with fruit trees (*e.g.* Del Vaglio *et al.* 2011).

Commuting routes

GPS-tracked *R. aegyptiacus* (N=10) exhibited long (14.491 ± 4.160 m), straight (straightness index: 0.95 ± 0.04) and fast (33.4 ± 3.1 km/hr) continuous commuting flight 130.7 ± 50.3 m above ground (Tsoar *et al*. 2011).

[1] Only species with available literature data were included in this review.

Recommendations for conservation and management

- Minimise pesticide spraying in orchards and gardens.
- Ensure fruit availability year round. Consider planting orchards of trees fruiting at times with low fruit availability.

Rhinolophus hipposideros (Lesser Horseshoe Bat)

Figure 6.2. Rhinolophus hipposideros. © Lena Godlevska

Feeding areas

R. hipposideros is mainly a forest bat in Europe (Bontadina *et al*. 2002, Reiter 2004, Zahn *et al.* 2008a, Reiter *et al.* 2013). It forages in all types of woodlands, even coniferous ones, but with a preference for deciduous and riparian forests. It also forages over pastures, along hedgerows, forest roads, tree lines and along pond and lake shores (McAney & Fairley 1988, Jones & Rayner 1989, Barataud 1992, Schofield 1996). These bats often use night roosts in buildings when foraging (Knight & Jones 2009).

The mean feeding area of a colony of 50–100 individuals was estimated at 12 km^2 (Roué & Barataud 1999), whereas in Bavaria the individual home range varied between 6.8 to 62.7 ha (mean 25.2 ha) and a core feeding area – between 2.8 and 8.2 ha (mean 5.3 ha) (Zahn *et al.* 2008a), which is nearly the same (0.4–22 ha, mean 6.3 ha) in Corsica (Beuneux *et al.* 2008).

The distance to feeding areas from the maternity roost varies with the size of the colony and the availability of suitable habitats from a few hundred metres up to 8 km (Schofield 1996, Beuneux *et al.* 2008) but usually between 1 and 2.5 km. A female can visit up to seven feeding areas in three nights (Holzhaider *et al.* 2002).

Diet

R. hipposideros preys upon Lepidoptera, Diptera, Neuroptera (McAney & Fairley 1989, Beck *et al.* 1989, Artois *et al.* 1990, Godat *et al.* 1991, Beck 1995, Vaughan 1997, Motte 1998, Williams *et al.* 2011).

Critical feeding areas

Riparian woodlands, wooded ravines and a network of habitats with deciduous woods, interspersed with ponds or brooks, small pastures, scrubs and hedgerows. Especially important are forested areas around the maternity roost (Roué & Barataud 1999, Reiter *et al.* 2013).

Commuting routes

R. hipposideros commutes along linear features such as rivers, ravines, hedgerows and tree lines (Schofield 1996, Motte 1998). These features should be linked to the roost (Motte & Libois 2002). It may directly cross a lake up to 1.2 km wide (Zahn *et al.* 2008a).

Recommendations for conservation and management

- Attention should be paid to management of areas within 3 km around maternity roosts.
- Maintain and restore linear structures between roosts and feeding areas (hedgerows, tree lines *etc.*).
- Avoid light trespass. To prevent cutting off commuting routes, unlit flyways should be provided either over the road (green bridge) or under it (tunnel).
- Maintain traditional land use (small pastures, extensive crops and orchards).
- Avoid pesticide use within feeding areas.
- Conserve night roosts in buildings within the home range.

Rhinolophus blasii (Blasius's Horseshoe Bat)

Figure 6.3. Rhinolophus blasii. © Mounir Abu-Said

Feeding areas

R. blasii is the rarest and least studied of the European horseshoe bats. It is found in karstic areas of south-east Europe, in landscapes characterised by a small-scale patchwork of shrub and open areas. It hunts in scrub, low growing broadleaf forests and along linear features such as hedgerows. These feeding areas are thought to be within 10 km of their day roosts. The limited radio-telemetry studies of this species found it hunting around vegetation between 0.5–5 m above the ground (Dietz *et al.* 2007). Experimental studies in flight cages reveal that it can also take prey from the ground (Siemers & Ivanova 2004).

Diet

The main prey for this species are moths, which make up over 95% of its diet in the Balkans (Dietz *et al.* 2007) and Jordan (Benda *et al.* 2010).

Critical feeding areas

Mosaic landscapes of shrubby vegetation, broadleaved woodland and hedgerows.

Commuting routes

R. blasii commutes along hedgerows and other linear landscape features.

Recommendations for conservation and management

- Attention should be paid to the management of areas within 10 km around maternity roosts.
- Maintain and create linear structures between roosts and feeding areas (hedgerows, tree lines *etc.*).

- Maintain traditional land use (small pastures, extensive farming and horticulture).
- Avoid pesticide use within feeding areas.
- Avoid light trespass.

Rhinolophus euryale (Mediterranean Horseshoe Bat)

Figure 6.4. Rhinolophus euryale. © Jens Rydell

Feeding areas

R. euryale typically hunts in structurally heterogeneous broadleaved woodlands and forests as well as in riparian vegetation (Russo *et al*. 2002, Siemers & Ivanova 2004, Russo *et al.* 2005, Némoz & Brisorgueil 2008). They seem well adapted to foraging in mosaic landscapes, such as those made of woodland patches interspersed with olive groves (Russo *et al*. 2002), or edge habitats such as hedgerows and woodland edges (Goiti *et al*. 2003, 2008, Barataud *et al.* 2009). Although plantations of broadleaved trees, native and exotic (*e.g. Eucalyptus*), may be used for foraging (Aihartza *et al.* 2003b, Russo *et al*. 2005), those of conifers are typically avoided (Russo *et al*. 2002), but their edges can also be selected (Barataud *et al.* 2009).

Foraging distances vary largely according to productivity of available habitats, sex, age class and reproductive season. Lactating females have been found to move more than non-lactating ones to reach their foraging sites. In optimal landscapes of Southern Italy, distances up to 5 km are recorded during lactation, with a mean distance of 2.2 km (Russo *et al*. 2002). Longer maximum distances of *c*. 9 km have been measured in the Iberian Peninsula (Russo *et al*. 2005, Goiti *et al*. 2006) and even 15.6 km in France (Némoz *et al.* 2008). Goiti *et al.* (2006) infer that the distance may depend on the colony size. Therefore, the larger the population to enhance or maintain is, the broader the scale of planning should be. Males moved less to reach feeding areas (mean 1.9 km), but this may be due to more frequent roost switching which may increase proximity to favoured feeding habitat. Newly volant juveniles flew on average 2.6 km from the roost (Goiti *et al*. 2006), whereas females forage at longer distances (Némoz *et al.* 2008).

Diet

R. euryale feeds on small moths (Goiti *et al.* 2004, Benda *et al.* 2006, 2010, Whitaker & Karataş 2009), other prey may seasonally become important (Goiti *et al*. 2004, Mikova *et al.* 2013).

Critical feeding areas

A highly structured, mosaic landscape with woodlands, meadows, shrublands and riparian vegetation.

Commuting routes

R. euryale follows hedgerows and other natural linear landscape features. They avoid urban settlements and lit up areas.

Recommendations for conservation and management

- Attention should be paid to management of areas within 5–10 km around maternity roosts.
- Avoid reforestation with conifers – prefer broadleaved species, particularly those native to the area.
- Avoid interruption of critical commuting routes by limiting growth of urban areas, roads and light trespass.
- Favour traditional management of agricultural landscapes and avoid pesticide use by encouraging organic farming.
- Habitat corridors, hedgerows, tree lines, stepping stones and in general a high landscape connectivity should be preserved.

Rhinolophus mehelyi (Mehely's Horseshoe Bat)

Figure 6.5. Rhinolophus mehelyi. © Jens Rydell

Feeding areas

Foraging habitats of *R. mehelyi* include a variety of woodlands that differ structurally, from open savannah-like woodlands to dense broadleaved and riparian forests (Rainho 2005, Russo *et al*. 2005, Salsamendi 2010, Rainho & Palmeirim 2013). Foraging activity seems closely related with habitat patches associated with water, sites where abundance of moths is higher – the main prey of Mehely's horseshoe bats (Rainho & Palmeirim 2011, Salsamendi *et al*. 2008, Salsamendi 2010, Salsamendi *et al.* 2012). Habitat suitability declines steadily with distance from the roost (Rainho & Palmeirim 2011).

Feeding areas and foraging distances differ largely between individuals, probably according to the availability of profitable foraging habitats around roosting sites. Mean foraging distances during lactation vary from 3.3 km to 19.2 km (52 % of animals forage at more than 10 km), requiring high energy costs of flight (Rainho 2011). Maximum individual foraging distances of 29 km have been recorded in the southern Iberian Peninsula (Rainho 2005, 2011, Salsamendi 2010). Mean feeding areas range from 0.6 km^2 to 4.5 km^2 (Russo *et al*. 2005, Salsamendi 2010).

Diet

R. mehelyi preys almost exclusively upon Lepidoptera (Gaisler 2001, Safi & Kerth 2004). In Turkey, Coleoptera, Hemiptera and Diptera were also present (Whitaker & Karataş2009).

Critical feeding areas

Woodlands with diverse structural complexity and close to water bodies near nursing roosts should be strictly protected. Traditional olive groves and eucalyptus plantations may also be important foraging habitats.

Commuting routes

R. mehelyi commutes mainly by following rivers and valleys, flying through or near to riparian vegetation, woodlands edges and tree lines (Salsamendi *et al.* 2012).

Recommendations for conservation and management

- Attention should be paid to management of areas within 12–15 km around maternity roosts.
- Specifically protect riparian forests.
- Promote landscape diversity favouring woodland types with diverse structural complexity.
- Maintain and create linear landscape elements.
- Preservation and creation of small water bodies (e.g. wetlands) near maternity roosts.
- Avoid the use of pesticides and insecticides in feeding areas and encourage traditional land management.
- Avoid light trespass.

Rhinolophus ferrumequinum (Greater Horseshoe Bat)

Figure 6.6. Rhinolophus ferrumequinum. © Jens Rydell

Feeding areas

In the UK, *R. ferrumeqinum* most often selects pasture, broad-leaved woodland and arable land with hedgerows as feeding habitats (Duvergé & Jones 1994, Duvergé 1996, Ransome & Hutson 2000, Flanders & Jones 2009). In Central and Western Europe, beside the use of extensively used grassland, a higher preference for forest habitats and edges, traditional orchards, hedges and riparian vegetation was determined (ASHG 1994, Bontadina *et al.* 1995, Bontadina *et al.* 1997, Pir *et al*. 2004, Boireau 2007). In Luxemburg, the species preferred semi-open, but richly structured habitats such as orchards, pastures and parklands instead of available broadleaf deciduous forests (Dietz *et al.* 2013a).

The mean foraging distances vary with the reproductive status, age and foraging strategy according to the season and weather conditions. Greater horseshoe bats may forage from the immediate surroundings of the colony up to a 14 km radius around the maternity roost (Duvergé

1996). Mean foraging distances from the maternity roost were 1.8 km for juveniles and up to 4.5 km for lactating females (Pir 1994, Pir *et al.* 2004, Dietz *et al.* 2013a), and 9.1 and 9.9 km for a pregnant and lactating female respectively (Boireau 2007).

Female *R. ferrumequinum* can visit up to 2–11 feeding areas in one night (mean size 3–7 ha) applying different hunting strategies (Ransome & Hutson 2000, Bontadina 2002, Boireau 2007, Dietz *et al.* 2013a).

Diet

Coleoptera, Lepidoptera, Hymenoptera and Diptera are the most selected prey components, but proportions of these groups may vary depending on local conditions (Jones 1990, Pir 1994, Beck 1995, Vaughan 1997, Boireau 2007, Flanders & Jones 2009, Whitaker & Karataş 2009, Fabbri & Giacomoni 2010). A meticulous year-round study in Germany found seasonal and even annual changes in the diet composition (Wolz 2018).

Critical feeding areas

Broadleaf woodlands and their edges, hedgerows, orchards, cattle-grazed pastures, meadows, shrub and riparian vegetation.

Commuting routes

Greater horseshoe bats use natural linear landscape features as hedges, tree rows, orchards, forest edges and forest tracks and riparian vegetation for commuting flights to their feeding areas. Streets are crossed at a low height of approximate 0.8–1 m. Greater horseshoe bats prefer crossing streets at places with a closed canopy.

Recommendations for conservation and management

- Special conservation management measures within urban areas of nursing colonies up to a radius of 1.8 km to enhance insect availability for juveniles.
- Conservation management measures (*e.g.* extensive cattle grazing) within the nursery's feeding area to enhance insect availability for lactating females.
- Coniferous forests should be transformed into broadleaved habitats within the feeding areas of Greater horseshoe bats.
- Preservation of broadleaved forest edges, orchards and hedges with hanging branches for perch hunting.
- Avoid interruption of critical commuting routes by limiting growth of urban areas and roads bypasses.
- Encourage the transformation of arable land into extensive pastures and meadows.
- Favour traditional management of agricultural landscapes and avoid pesticide use by encouraging traditional or organic farming.
- Favour landscape with a high natural heterogeneity: habitat corridors, hedgerows, tree lines and other natural stepping stones. In general high landscape connectivity should be preserved.
- Avoid the use of ivermectin or similar products as antiparasitic drugs in cattle stock farming within the hunting areas to preserve the coprophagous fauna of dung.
- Avoid light trespass.

Myotis alcathoe (Alcathoe Whiskered Bat)

Figure 6.7. Myotis alcathoe. © Suren Gazaryan

Feeding areas

M. alcathoe is a forest specialist, widely distributed in woodlands of Europe and the Caucasus, but its occurrence is rather patched and restricted to suitable forest habitats (Niermann *et al*. 2007, Gazaryan 2009, Coronado *et al.* 2017). In Greece, it hunts in small valleys with deciduous trees and flowing water (Helversen *et al*. 2001). In Central Europe, it forages among the trees or in clearings and over unpaved roads in old natural deciduous forests, around water bodies with patches of riparian vegetation, rather close to the vegetation. Depending on the season, bats also forage in gardens and over streams within settlements (Lučan *et al*. 2009, Schorcht *et al.* 2009, Danko *et al.* 2010). In forests, they prefer to hunt in the canopy (Plank *et al.* 2012).

Diet

Small Diptera are the most important prey item along with spiders, caddis flies, small moths and neuropterans according to Lučan *et al*. (2009), small moths and ants (Danko *et al.* 2010).

Critical feeding areas

Natural deciduous forests, patches of old woods with small water bodies. Mature oak and oak-hornbeam forests in Central Europe (Lučan *et al.* 2009, Dietz & Dietz 2015, Brinkmann *et al.* 2015) and other mature broadleaf forests further south in Europe and in the Caucasus are simultaneously critical feeding and roosting habitats for the species (Aggire-Mendi *et al.* 2004, Gazaryan 2009, De Pasquale & Galimberti 2014, Reiter *et al.* 2015, Coronado *et al.* 2017).

Commuting routes

Linear landscape elements such as streams and roads. *M. alcathoe* were found in road-kill (Řehák *et al*. 2008).

Recommendations for conservation and management

- Preservation of mature broadleaf forests.
- Maintenance and restoration of riparian vegetation.
- Avoidance of light trespass.

Myotis brandtii (Brandt's Bat)

Figure 6.8. Myotis brandtii. © Andreas Zahn

Feeding habitats and areas

M. brandtii feeds in woodlands and above and among stagnant water, rivers and streams (Taake 1984, Racey 1998, Meschede & Heller 2000, Dense & Rahmel 2002, Tupinier 2004). Coniferous forests were favoured over other forest types as well as over grassland and arable land in the study by Berge (2007). In the south of Europe, the species can only be found in mountainous woodlands. It is hardly ever found in urbanised habitats (Taake 1984, Tupinier 2004).

The species forages in areas from 1.5 km up to 10 km from its roost (Dense & Rahmel 2002). In Germany, radiotracked females used 2–13 different feeding areas (Meschede & Heller 2000, Dense & Rahmel 2002).

Diet

M. brandtii preys mainly on Lepidoptera and Diptera (Taake 1992, Vaughan 1997, Whitaker & Karataş 2009). In Finland, geometrid and tortricid moths constituted half of its diet and one third were mosquitos, midges, and flies (Vesterinen *et al.* 2018).

Critical feeding areas

Large blocks of old woods, over stagnant waters, in riparian habitats, along tree lines and hedgerows.

Commuting routes

Individuals use fixed routes along wood lanes, hedges and forest edges (Dense & Rahmel 2002). Ekman & de Jong (1996) showed that *M. brandtii* was often absent at isolated patches of woodland within an agricultural landscape and on lake islands, indicating that the species does not readily cross open areas such as crop fields or lakes.

Recommendations for conservation and management

- Maintenance of flying corridors between roosts and foraging habitats.
- Conservation and restoration of woodlands and riparian zones around roosts.
- Avoidance of light trespass.

Myotis mystacinus (Whiskered Bat)

Figure 6.9. Myotis mystacinus. © Suren Gazaryan

Feeding areas

M. mystacinus forages in forests, along woodland edges and river banks. More open areas such as parks and hedges might be used as well. Taake (1984) found an association with agricultural landscapes and riparian habitats surrounding roosts in Germany. In Slovakia, it is a woodland generalist without association to a particular forest type (Kanuch *et al.* 2008). For Ireland, Buckley *et al.* (2013) reported that the species mostly used mixed woodland and riparian habitats as core feeding areas.

Several feeding areas up to 2.8 km from the roost can be used (Cordes 2004). Recent studies have indicated that the species clearly favoured grassland over built-up areas, woodland and arable land (Berge 2007). In the study of Berge (2007), *M. mystacinus* had few feeding areas at distances of 200–2,300 m from the roost, while the average was 812 m (Berge 2007). In a German study, the average distance between maternity roosts and feeding areas was around 1 km (Simon *et al.* 2004).

Diet

In Czechia, *M. mystacinus* preys on Chironomidae/Ceratopogonidae (29%), Araneida (29%) and Trichoptera (19.9%) (Pithartová 2007). However, they mostly consumed Lepidoptera in Turkey (Whitaker & Karataş 2009).

Critical feeding areas

Key foraging habitats are grassland (Berge 2007), mixed woodland and riparian habitats (Buckley *et al.* 2013).

Commuting routes

In a study on the echolocation behavior, it was observed that whiskered bats followed a hedgerow (Holderied *et al.* 2006). This suggests the importance of landscape elements that can provide acoustic "landmarks" to the species.

Recommendations for conservation and management

- Retain and restore grasslands, wetlands and riparian habitats.
- Save hedgerows and riparian vegetation within the radius of 3 km around the roost.
- Avoid light trespass.

Myotis capaccinii (Long-fingered Bat)

Figure 6.10. Myotis capaccinii. © Branko Karapandža

Feeding areas

M. capaccinii typically forages in riparian habitats and over lakes (Kalko 1990, Médard & Guibert 1990, Russo & Jones 2003, Almenar *et al.* 2009), preferring calm waters bordered by well-developed riparian vegetation and large (over 5 m) inter-bank distances (Biscardi *et al.* 2007). It forages low over the water surface (17.5 ± 4.6 cm, Kalko 1990). The most suitable patches in terms of prey accessibility and availability are selected (Almenar *et al.* 2013). However, the species occurs on some Mediterranean islands, where water bodies are very rare. In one of such case (Zakynthos) *M. capaccinii* was found hunting in woodlands (Davy *et al.* 2007).

In Central Italy, Biscardi *et al.* (2007) observed a mean distance of 7.5 km from a roost to feeding areas, with a maximum of 21 km. In Spain, the distance up to 22.7 km was reported by Almenar *et al.* (2011). In Corsica, the mean distance between a maternity roost and a foraging habitat was 19.7 km and the maximum was 31 km (straight line) or 54 km along the river (Rist *et al.* 2010). The foraging distance varied according to the reproductive status of the bats. They forage closer to the roost during pre-breeding and weaning periods, whereas lactating females tend to spread further along the river stretch (Némoz & Brisorgueil 2008). Foraging activity drops during very windy nights, therefore trees bordering water sites are also valuable for sheltering feeding areas from the wind (Russo & Jones 2003).

Diet

M. capaccinii trawls Diptera (Chironomidae), Lepidoptera, Trichoptera (Médard & Guibert 1992, Almenar *et al.* 2008, Whitaker & Karataş 2009) and even small fish (Aihartza *et al.* 2003a, Aizpurua *et al.* 2013) from the water surface.

Critical feeding areas

Water bodies with large inter-bank distances, calm or static open water surfaces and lush riparian vergetation.

Commuting routes

M. capaccinii often follows waterways but may cross open areas (Almenar *et al.* 2009).

Recommendations for conservation and management

- Preserve or restore riparian vegetation, especially in the areas surrounding main cave roosts, but also over longer distances (> 20 km) around them.
- Avoid deterioration of riparian ecosystems, including pollution, channelisation, dredging and damming.
- Avoid light trespass.

Myotis dasycneme (Pond Bat)

Figure 6.11. Myotis dasycneme. © Suren Gazaryan

Feeding areas

M. dasycneme is a trawling bat. It can forage at a distance of up to 15 km from the roost and even up to 25 km during spring and autumn (Haarsma & Tuitert 2009). Although they are specialised in trawling insects from the water surface, they are quite flexible in terms of foraging habitat. The species is most abundant in habitats with a combination of lakes, a dense network of waterways, marshland and meadows. They mostly hunt above large water bodies and rivers with still water. In the Netherlands they spent 25 % of their foraging time above meadows (Haarsma & Siepel 2014). In Poland they foraged in an open-canopy alder swamp forest and over a meadow (Ciechanowski *et al.* 2017).

Published data on radio-tracking studies of pond bats is limited to studies in post-glacial lakelands of northern Poland. Feeding areas of pregnant females are located up to 23.8 km (mean 11.4 km) from the nursery roost (the whole commuting route between all visited foraging sites may cover up to 54 km during one night). They forage mostly over eutrophic lakes but significantly prefer fish ponds, even if they constitute only a small portion of their home range. Later, during lactation they switch to mesotrophic lakes and small, often fast-flowing rivers but also artificial canals. Feeding areas of lactating females are located significantly closer, up to 22.0 km (median only 2.9 km). (Ciechanowski *et al.* 2017). This habitat switch may explain dietary shift from chironomids to reophilous caddis flies in the same period (Ciechanowski & Zapart 2012). In the Netherlands the feeding areas are located on average 8 km away from maternity roosts and 12 km from male roosts (Haarsma, *pers. com).*

Diet

Pond bats prey mostly on small Dipterans such as Chironomids and Culicidae, but also on moths and beetles (Britton *et al*. 1997, Sommer & Sommer 1997). The diet in Poland is dominated by non-biting midges (Chironomidae – both imagines and pupae) and caddis flies (Trichoptera) (Ciechanowski & Zapart 2012) and differs significantly from Daubenton's bats (Krüger *et al.* 2014).

Critical feeding areas

Bodies of water, waterways, but also marshlands and to a lesser extent meadows. Insect-rich habitats are important for reproducing females and their offspring, especially during spring and autumn (Haarsma & Siepel 2014, Ciechanowski *et al.* 2007, 2017).

Commuting routes

Pond bats can easily cross open areas, like arable land or fly above large blocks of coniferous plantations (Ciechanowski *et al*. 2017). Waterways, such as canals and rivers, as well as other linear elements such as tree lines and hedgerows are used as commuting routes (Verboom *et al*. 1999, Haarsma & Siepel 2014).

Recommendations for conservation and management

- Management of water bodies and other important habitats around nursery roosts in oder to maintain insect abundance.
- Conservation of linear water bodies within a radius of less than 6 km around

nursery roosts because they serve both as commuting routes and feeding areas.

- Development of duckweed and eutrophication is to be prevented.
- Preservation of trees growing on river banks and lake shores.
- Light trespass is to be avoided.

Myotis daubentonii (Daubenton's Bat)

Figure 6.12. Myotis daubentonii. © Lena Godlevska

Feeding areas

M. daubentonii is associated with aquatic habitats, where it preys either on the wing or trawls the water surface with its feet and/or its wing membrane (Kalko & Schnitzler 1989). Hence, *M. daubentonii* forages mainly above flowing or static water, preferring the latter. The species avoids water surfaces which are cluttered or covered with duckweed (Boonman *et al.* 1998, Rydell *et al.* 1999, Todd & Waters 2017). Similarly, development of invasive plant species may decrease the suitability of waterways for foraging (Lintott *et al.* 2015).

Given the abundance and wide distribution of the species in Europe, it is often used as a surrogate indicator of the riparian habitat quality (*e.g.* López-Baucells *et al.* 2017).

Feeding areas are usually at a maximum distance of 2–5 km from the roosts (Arnold *et al*. 1998, Parsons & Jones 2003, Dietz *et al*. 2006), but may occasionally be as far as 10 km away from the roost. Females tend to forage closer to their roost than males (Encarnação *et al*. 2005, Lučan & Radil 2010). Altitudinal habitat segregation between sexes was described for this species across the European and Caucasian range: males tend to occupy upstream areas and females exploit more productive habitats at lower elevations (Leutzinger & Brossard 1994, Russo 2002, Gazaryan 2003, Encarnação 2012, Nardone *et al.* 2015).

Feeding areas of pregnant and lactating females are typically small. After the young are weaned females also use larger areas (Dietz *et al*. 2007). Females show a high fidelity to quality feeding areas (Kapfer *et al*. 2008) even though they might change the roost quite often.

Diet

M. daubentonii preys on Chironomidae/Ceratopogonidae, Diptera and Trichoptera (Flavin *et al.* 2001). Terrestrial insects like Brachycera or Coleoptera were also detected in Germany and Finland (Vesterinen *et al.* 2013, 2018, Krüger *et al.* 2014).

Critical feeding areas

Availability of ponds, rivers and other water bodies with high insect production close to the roosts is very important, especially for lactating females and juveniles.

Commuting routes

M. daubentonii uses waterways and tree lines as commuting routes (Downs & Racey 2006). They prefer water bodies with bankside vegetation both for commuting and feeding (Warren *et al*. 2000, Lisón & Calvo 2011).

Recommendations for conservation and management

- Attention should be paid especially to the management of areas within ~ 2 km of maternity roosts.
- Maintenance and enhancement of bankside vegetation and tree cover in association with open water surfaces (devoid of duckweed, reed and invasive plants).
- Retain low-intensity agriculture, promote spatial and temporal landscape heterogeneity and reduce pesticide use.
- Parkland, woodland and open-water habitats, tree lines and other linear structures should be conserved.
- Avoidance of light trespass.
- Creation of artificial wetlands (*i.e.* construction of retention ponds) in the agricultural landscape (Stahlschmidt *et al.* 2012).

Myotis emarginatus (Geoffroy's Bat)

Figure 6.13. Myotis emarginatus. © Jens Rydell

Feeding areas

Geoffroy's bats are "flexible specialists" in terms of feeding. Foraging bats rely on a gleaning strategy and hunt in clutter (*e.g.* Clarin *et al.* 2013). They may feed in forest habitats (Krull *et al.* 1991, Demel *et al.* 2004, Flaquer *et al.* 2008, Zahn *et al.* 2010) and in traditionally managed farmland (Dietz *et al.* 2013a), olive groves (Flaquer *et al.* 2008) and riparian areas (Russo & Jones 2003, Dietz *et al.* 2013a). In Iberia, these bats forage mainly in pine plantations, riparian woodland and scrubland, whereas native dehesa (a loose semi-natural oak *Quercus rotundifolia* and *Q. suber* woodland) is not exploited (Goiti *et al.* 2010).

In the north part of its range (Germany, the Netherlands, Luxembourg), it feeds in cow sheds and stables (Krull *et al.* 1991, Brinkmann *et al.* 2001, Zahn *et al.* 2010, Dekker *et al*. 2013, Pir & Dietz 2018). In a rural Mediterranean landscape, adults foraged farther than juveniles (3.4 vs. 1.8 km), with a maximum distance of over 6.5 km from the roost (Flaquer *et al.* 2008).

In Upper Bavaria, females foraged at up to 8.1 km around their colony roost. The average distance to the foraging area was 3.7 km. 70 % of feeding areas were located within 5 km and 90 % within 6 km of the nurseries (Zahn *et al.* 2010). In Luxembourg, this species preferred more open, but richly structured traditional farmland habitats such as orchards, pastures and parkland habitats instead of available large broadleaf forests. Mean flight distances between nursing colonies and hunting areas varied between 4.2 and 5.2 km. Maximum distances of 8.8 to 12.2 km were recorded. Mean home range sizes were 438.6 – 694.7 ha with individual hunting areas 20.1 – 55.3 ha (Dietz *et al.* 2013a, Pir & Dietz 2018).

Diet

The diet largely consists of Diptera (Krull *et al*. 1991, Beck 1995, Rakhmatulina 2005, Steck & Brinkmann 2006, Vernier & Guzzo 2007, Goiti *et al.* 2010, Kervyn *et al.* 2012). However, Hemiptera prevailed in Turkey (Whitaker & Karataş 2009) and Coleoptera in Jordan (Benda *et al.* 2010).

Critical feeding areas

Forests, traditional farmland, riparian habitats and stables.

Commuting routes

M. emarginatus prefers sheltered routes in forests. It may cross urban settlements but major roads and open areas are avoided (Flaquer *et al*. 2008). In the north, the species used tree lanes to move from roosts to feeding areas (Brinkmann *et al.* 2001, Dekker *et al*. 2013). In Luxemburg and Bavaria, commuting flights between the maternity roosts and feeding areas were observed along linear elements such as hedgerows, vegetation along streams and small forested patches (Zahn *et al.* 2010, Dietz *et al.* 2013a).

Recommendations for conservation and management

- Preserve richly structured woodland and traditional extensively farmed habitats with a high landscape heterogeneity.
- Ensure cattle stables are accessible to bats.
- Improve and maintain connections between roosts, feeding areas and hibernating/swarming sites by creating or preserving forest corridors, hedgerows, riparian vegetation and tree lines.
- Avoid the use of pesticides and anti-parasitic drugs in livestock farming, especially near roosts and in cow sheds.
- Promote solitary trees, tree alleys, parks and green walls made up of native species within urban areas.
- Avoid light trespass.

Myotis bechsteinii (Bechstein's Bat)

Figure 6.14. Myotis bechsteinii. © Manuel Ruedi

Feeding areas

M. bechsteinii prefers old open deciduous forests (Wolz 1992, Kerth *et al*. 2002, Lüttmann *et al.* 2003). It was also found in highly structured coniferous forests (Albrecht *et al*. 2002, Napal *et al.* 2010, Arrizabalaga-Escudero *et al.* 2014) and Mediterranian shrublands in the Caucasus (Gazaryan 2007). Bechstein's bats had a significant preference for the canopy level during pregnancy, lactation and post-lactation (Plank *et al.* 2012).

In areas with isolated woodlands, *M. bechsteinii* forages also in an agricultural landscapes with a mosaic of habitats: pastures, hedgerows, parks, old trees, old extensive orchards (Schofield & Morris 2000, Lüttmann *et al*. 2003, Barataud *et al*. 2005). Younger woodlands with some older stands are also used, if they provide a closed canopy and an understorey with a mosaic vertical structure (Dietz & Pir 2009).

Feeding areas in Germany were estimated to be 17.5–20 ha located within a 0.2–2 km radius of the roost (Wolz 1992, Kerth *et al.* 2001, Luttmann *et al.* 2003). In southeastern France the distance was longer (1.3 ± 0.9 km) and sometimes up to 3.9 km. Feeding areas are also larger (190 ± 150 ha, Girard-Claudon 2011, Vernet *et al*. 2014). Each maternity colony switches roosts, which are usually less than 1 km, but sometimes up to 4.5 km apart (Schofield *et al.* 1997). The size of the activity area is greater in a fragmented woodland habitat than in a large block of forest (Schofield & Morris 2000, Kerth *et al*. 2001, 2002, Albrecht *et al*. 2002, Lüttmann *et al.* 2003, Greenaway & Hill 2004, Napal *et al.* 2013). The smallest feeding areas (0.83–7.10 ha, mean 3.41 ha) were recorded in the Upper Rhine Valley in Germany, presumably indicating a very high habitat quality of the study area (Brinkmann *et al.* 2007).

In Germany, Bechstein's bats hunted almost exclusively in the canopy, preferring crowns of oak trees (Güttinger & Burkhard 2013).

In England and Wales, the activity was significantly higher over water on organic farms versus conventional ones (Wickramasinghe *et al.* 2003).

Diet

Mainly feeds upon Diptera, mostly Tipulidae, Lepidoptera and Coleoptera and locally or seasonally on Orthoptera (Taake 1992, Vaughan 1997, Wolz 1993a, b, Beck 1995, Andreas *et al.* 2012).

Critical feeding areas

Large stands of old deciduous and richly structured broadleaf forests with clearings are critical feeding areas for Bechstein's bat. It favours windthrow gaps due to the amount of dead wood and the many herbaceous plants. These facilitate the development of saprophytic insects which are numerous in the diet (Barataud *et al*. 2005).

Commuting routes

Usually commutes only within the forested area and prefers to take underpasses for crossing motorways (Kerth & Melber 2009).

Recommendations for conservation and management

- The proportion of mature deciduous forest should be increased.

- Unmanaged forest patches containing numerous trees with cavities and windthrow gaps should be retained.
- Clear-cutting of large areas near roosts must be avoided.
- Forest continuity should be favoured by promoting corridors connecting networks of important sites.
- High underpasses should take precedence over other mitigation methods in the road construction.
- Bat-friendly management of woodlands within 2 km of the roosts is necessary.
- Spraying of pesticides in forests should be banned.
- Maintenance of organic water habitats.
- Avoidance of light trespass.

Myotis nattereri (Natterer's Bat)

Figure 6.15. Myotis nattereri. © Suren Gazaryan

Feeding areas

Meadows, pastures, orchards, broad-leaved woods, to open coniferous forests and riparian habitats (Arlettaz 1996b, Siemers *et al.* 1999, Parsons & Jones 2003, Siemers & Swift 2006, Smith & Racey 2008, Meier & Trappmann 2011, Lundy *et al.* 2012). Intense foraging was observed inside cattle sheds (Simon *et al.* 2004).

Feeding areas range between 128 and 580 ha (Fiedler *et al*. 2004, Siemers *et al*. 1999, Smith & Racey 2008). The core of a feeding area can be up to 4 km away from the roost and individuals are faithful to them, returning there regularly. Commuting routes between the roost and the core area are also utilised for foraging (Siemers *et al.* 1999). In a German study, the average distance between maternity roosts and feeding areas was 1.5 km (Simon *et al.* 2004).

Diet

M. nattereri can capture prey on the wing and by gleaning resting insects from the surface of vegetation using the tail membrane and/or feet (Arlettaz 1996b, Swift 1997, Swift & Racey 2002). The chief components of its diet are Diptera and Coleoptera, especially Brachycera and Curculionidae. Diurnally active insects, insects which rarely fly and non-flying arthropods are also eaten (Bauerová & Červeny 1986, Gregor & Bauerová 1987, Shiel *et al.* 1991, Siemers & Swift 2006). Grillidae are the major food component in Turkey (Whitaker & Karataş 2009).

Faecal pellets collected at a hibernation site in southern England for two winters, indicated that *M. nattereri* forages throughout winter on non-volant Aranea, Isopoda and Lepidoptera (Hope *et al.* 2014).

Critical feeding areas

Broadleaved riparian woodland, open coniferous forest, orchards and grassland and the interior of sheds.

Commuting routes

Commuting bats follow hedgerows and waterways with riparian vegetation. They are particularly important in areas where the foraging habitats are fragmented (Simon *et al.* 2004).

Recommendations for conservation and management

- Retain broadleaved forests and haylands.
- Maintain diverse hedgerow structure in grassland areas for both roosting and commuting.
- Keep cattle sheds and stables accessible to bats.
- Maintain, restore and preserve bankside vegetation.
- Avoid application of insecticides in orchards and grassland.
- Avoid light trespass and keep sheds unlit.

Myotis blythii (Lesser Mouse-eared Bat)

Figure 6.16. Myotis blythii. © Branko Karapandža

Feeding areas

M. blythii avoids forests and prefers dense steppe vegetation as opposed to sparse xeric grassland, unmown meadows or pastures (Arlettaz 1995, 1999). *M. blythii* also forages in wet meadows which support more insects than pastures (Güttinger *et al*. 1998), but can switch from traditional feeding habitat with 0.3–1.2 m tall grass to secondary (usually temporary) foraging grounds (Arlettaz 1996a).

The mean size of feeding areas is 38.1 ± 11 ha. These bats can forage in mountain habitats and in Switzerland the mean altitude of feeding areas was 1,012 ± 317 m, with the highest records at 2,000 m a.s.l. The mean distance to feeding areas from a nursery roost was 3.8 ± 1.5 km (Arlettaz 1995). The furthest feeding grounds were observed at the distance of 10.9 km (mean 6.3 km, Güttinger *et al*. 1998) and 22 km (Groupe Chiroptères de Provence *pers. comm.*).

Diet

Bush crickets, sometimes replaced by cockchafers in the spring (Arlettaz *et al.* 1993, 1997, 2001, Whitaker & Karataş 2009, Siemers *et al.* 2011).

Critical feeding areas

Grasslands with lush vegetation, shrublands and orchards.

Commuting routes

In Switzerland, *M. blythii* flew strait to the feeding grounds from the roost (Arlettaz 1996a).

Recommendations for conservation and management

- Maintenance of pastures and open grasslands, which should not be overgrazed.
- Extensive grazing is however recommended on dry grasslands to avoid the development of encroaching woody vegetation.
- Light trespass is to be avoided.

Myotis myotis (Greater Mouse-eared Bat)

Figure 6.17. Myotis myotis. © Peter Estok

Feeding areas

M. myotis prefers broadleaved, mixed or coniferous open woodlands with a sparse or absent understorey, grazed woods or olive groves. It also forages above freshly cut meadows, harvested fields, intensively cultivated orchards, and avoids scrubs (Audet 1990, Schmidt 2003, 2008, Wojtaszyn 2008, Rainho 2011).

Among 28 foraging sites determined during a German radio-tracking study, 16 were in forests and 12 in more open countryside, such as meadows and fields (Zahn *et al.* 2005). It can also hunt around buildings in rural areas (Zahn *et al.* 2008b).

In Portugal, *M. myotis* mainly favours areas of sparse montado, where grazing prevents scrub encroachment and shortens grass, thus facilitating access to its ground-dwelling prey (Rainho *et al.* 2010, Rainho & Palmeirim 2013).

Feeding areas were situated at a maximum distance of 25 km from the roost, but usually within 5–15 km (Audet 1990, Arlettaz in Roué & Barataud 1999, Rudolph *et al.* 2009). Size of feeding areas: 100–1,000 ha, with a mean of 350 ha in Portugal (Rainho & Palmeirim 2013).

Diet

Ground beetles (especially carabids) are the dominant insect group in the diet during all seasons in Europe and Turkey (Bauerová 1978, Graf *et al.* 1992, Beck 1995, Arlettaz *et al.* 1993, 1997, 2001, Whitaker & Karataş 2009, Graclik & Wasielewski 2012). The second most important dietary component was Gryllidae in Switzerland, Portugal, Spain and Turkey (Arlettaz *et al.* 1997, Pereira *et al.* 2002, Whitaker & Karataş 2009), Tipulidae in Belgium and Bavaria (Kervyn 1996, Zahn *et al.* 2006) and spiders in Poland (Graclik & Wasielewski 2012).

Critical feeding areas

Open deciduous woodlands without a lush understorey are essential for the species. It can be affected by practices that decrease prey availability (Zahn *et al.* 2007).

Commuting routes

Female *M. myotis* commute directly from roosts to foraging grounds (Krainer *et al.* 2017, Egert-Berg *et al.* 2018).

Recommendations for conservation and management

- Maintenance of corridors between roosts and foraging habitats.
- Maintenance of forest alleys clear of vegetation.
- Promotion of extensive grazing in forests to create a mosaic of ground-cover vegetation.
- Control of shrubs.
- Avoidance of pesticide use within the home range of a nursery.
- Avoidance of light trespass.

Myotis punicus (Maghrebian Mouse-eared Bat)

Figure 6.18. Myotis punicus. © Raphael Sane

Feeding areas

Corsican studies in 1999 when the species was still considered as *M. myotis* (Beuneux 1999) mentioned that its foraging habitats differed from those of continental *M. myotis*, with a preference for pastures and grassland-wood ecotone (Beuneux 2002, 2004). Radio-tracking studies were carried out in 2009–2011 and 44 foraging grounds of 9 habitat types were identified for 53 gestating or lactating females (Beuneux *et al.* 2014). The preferred foraging grounds of *M. punicus* are open habitats with sparse vegetation: pastures (62 %), mown hay meadows (9 %), unmown grasslands (7 %), but also orchards and vineyards. In Corsica and Malta, the species has been observed searching for prey in slow flight at less than 1 m from the ground, landing to catch it and taking off quickly (Borg 1998).

Feeding areas vary from 1–25 ha (mean 8.1 ± 5,8 ha) and they represent less than 10 % of the individual bat MCP (minimum convex polygon). Mean distances to the feeding areas of three maternity colonies were 3.6, 4.9 and 6.0 km respectively, with a maximum straight-line distance of 16.5 km (Beuneux *et al.* 2014).

Diet

Orthoptera, Lepidoptera and Coleoptera in Malta. In Corsica, it feeds mainly on Orthoptera, Coleoptera and Lepidoptera (Beuneux 2002) and occasionally on Homoptera (Arlettaz 1995).

Critical feeding areas

Open habitats with sparse vegetation.

Commuting routes

Not studied.

Recommendations for conservation and management

Preservation of extensive sheep and cattle farming for maintaining xeric grasslands.

Nyctalus lasiopterus (Greater Noctule)

Figure 6.19. Nyctalus lasiopterus.
© Suren Gazaryan

Feeding areas

In southern Spain populations roosting in urban parks preferred to exploit urban areas and open lands for foraging as opposed to woodlands (Popa-Lisseanu 2007, Popa-Lisseanu *et al.* 2009). In Portugal oak woodlands were reported to be important (Rainho 2007). In Corsica, where the studied population consisted only of males, the feeding areas were mountainous wooded areas, high ridges, coastal habitats destroyed by fire (previously woodlands), eucalyptus and citrus fruit plantations and vegetable fields (Beuneux *et al.* 2010). In continental France radio-tracking studies demonstrated that several individuals foraged over pastures (Destre 2007), close to rivers, above wet meadows and the canopy of deciduous forests (Dubourg-Savage *et al.* 2013, 2014a).

In southern Spain greater noctules (including lactating females) regularly forage up to 40 km from the roost because of the lack of roosts around feeding habitats. An extraordinary distance of 92 km from the roost has also been recorded (Popa-Lisseanu *et al.* 2009). In Corsica, the mean distance to the feeding areas can reach 25 km (Beuneux *et al.* 2010).

Diet

With prey items such as Coleoptera, Lepidoptera, Heterocera, Odonata, Heteroptera, Hymenoptera, Diptera and Trichoptera, *N. lasiopterus* demonstrates an opportunistic diet that may include small birds (Dondini & Vergari 2000, 2004, Ibáñez *et al.* 2001, Uhrin *et al.* 2006, Lugon 2008, Popa-Lisseanu *et al.* 2007, Smirnov & Vekhnik 2013, Dubourg-Savage *et al.* 2014b).

Critical feeding areas

Insect-rich habitats such as wetlands, open lands and sometimes woodlands.

Commuting routes

Commutes directly to feeding areas.

Recommendations for conservation and management

- Maintain insect diversity and abundance in grass- and woodlands.
- Avoidance and mitigation programme must be implemented in wind farm projects.

Nyctalus leisleri (Leisler's Bat)

Figure 6.20. Nyctalus leisleri. © Lena Godlevska

Feeding areas

The foraging behaviour of *N. leisleri* depends on the season, age, sex and geographical position of the site. In southern England Leisler's bats significantly preferred foraging in areas of woodland and along scrub-lined roads in Kent, but over pasture around Bristol. Urban and arable areas were avoided at both sites. Bat-detector transects showed a significant preference for hunting along woodland margins (Waters *et al*. 1999).

In Ireland, two-thirds of the recorded foraging time was spent over pastures or drainage canals. Foraging over other habitats, particularly lakes and conifer forests was greatest in pre-parturition. Other foraging habitats included lit-up areas, estuaries, streams, beaches and dunes. Illuminated places were the most favoured foraging sites (Shiel & Fairley 1998, Shiel *et al*. 1999). In the east of Germany the species foraged in large woodland areas without preference for a particular forest type, in open landscapes and at waters, as well as in settlements (Schorcht 2002). In south-western Germany, the foraging activity was concentrated at lakes and rivers near forests, along forest roads and above clearings (Harbusch *et al*. 2002).

In Italy, foraging activity of *N. leisleri* was recorded by acoustic surveys in all habitat types except coniferous plantations and arable areas (Russo & Jones 2003). Sites with roosts appeared to be closer to main roads and streams than random sites (Spada *et al.* 2008).

In England, most activity was observed at rivers, lakes and improved pasture (Vaughan *et al*. 1997). In Corsica, 76 % of Leisler's bat feeding areas are in cluttered environments (small forested valleys and within woodlands), 21 % in semi-open habitats (windthrow gaps in woods, orchards/ pastures, xeric grasslands with shrubs) and 3 % at ponds (Chalbos 2013).

Female and male home ranges in Germany were estimated to be at least 6 and 1.5 km^2 respectively (Fuhrmann *et al.*). Maximum distances of foraging flights could be over 17 km, but usually about 5 km from the roost (Shiel *et al*. 1999, Waters *et al*. 1999, Schorcht 2002). In Germany females foraged further away from the mating and stopover sites than males (Hurst *et al.* 2016).

Diet

The major prey is Diptera, Lepidoptera, Coleoptera and Trichoptera (Beck 1995, Shiel *et al.* 1998, Waters *et al.* 1999). In Slovakia, the proportion of Diptera, Hymenoptera and Coleoptera increased from May-August due to decreasing Lepidoptera (Kanuch *et al.* 2005).

Critical feeding areas
Water bodies, forest roads and clearings, pastures.

Commuting routes
Commutes directly to foraging sites (*e.g.* Shiel *et al*. 1999).

Recommendations for conservation and management

- Riparian vegetation should be protected and encouraged, areas of largely or completely unmanaged woodland should be maintained where possible, habitat interruptions should be avoided in logging protocols.
- The size of logged patches should be minimised and corridors between main blocks of woodland should be maintained.
- Native broadleaved trees are desirable in reforestation and afforestation.
- Farmland practices should enrich landscape complexity, favour structural variation and connectivity, and limit the spread of pesticides.
- Wind farms shall not be sited within feeding areas around maternity roosts.
- Mitigation programmes must be designed and implemented before the deployment of new wind farms.
- Mitigation measures shall be undertaken for operating wind farms.

Nyctalus noctula (Common Noctule)

Figure 6.21. Nyctalus noctula. © Suren Gazaryan

Feeding areas
Open water bodies, woodlands, wetlands, riparian habitats, valley pastures, harvested fields and illuminated places in settlements (Austria: Spitzenberger 2001, Czech Republic: Gaisler *et al*. 1979, Bartonička & Zukal 2003, Denmark: Baagøe 2001, Germany: Kronwitter 1988, Meschede & Heller 2000, Greece: Hanak *et al*. 2001, Italy: Russo & Jones 2003, Latvia: Rydell & Petersons 1998, Luxembourg: Harbusch *et al*. 2002, Poland: Rachwald 1992, Spain and Portugal: Benzal *et al*. 1991, Russia: Strelkov & Ilyin 1990, Switzerland: Stutz & Haffner 1989, Gebhard & Zingg 1995, the Netherlands: Limpens & Kapteyn 1991, the UK: Vaughan *et al*. 1997, Ukraine: Bashta 2011). In Poland noctules selected lakes, ponds, rivers, canals and coastal lagoons, while they avoided mixed forests, tree lines, hedgerows and roads in coniferous forests and arable

land, at least during pregnancy and lactation (Ciechanowski 2015).

In feeding areas, bats flew at 6.0 ± 2.1 m/s (Jones 1995). Foraging flights can easily be more than 10 km away from the roost (Meschede & Heller 2000) and can be up to 20 km (Limpens *et al*. 1997, Heise 1989). However, the main activity of a maternity colony in Germany was within a radius of approximately 2 km from the colony's roost (Schmidt 1988).

The minimum convex polygon (MCP) used by a colony in the UK was 62,750 ha and the mean individual bat MCP was 820 ha. A comparison of the habitat use for foraging between lactating and non-lactating bats demonstrated regional differences. Regardless of reproductive status, broadleaf woodland and pasture were consistently preferred. Non-lactating bats used marginal habitats (arable land and moorland) significantly more than lactating bats (Mackie & Racey 2007).

A German study found no sex-related differences in the size of home ranges (females 2.051 ± 2.096 km^2, males 2.252±1.391 km^2) or in the habitats used. Noctules foraged mostly in lacustrine habitats (Dechmann *et al.* 2014).

Diet

In the UK, the majority of the diet consisted of Diptera, Lepidoptera and Coleoptera in approximately equal proportions (Mackenzie & Oxford 1995). It was more diverse in Germany, where substantial amounts of Hymenoptera, Diptera and Trichoptera (Beck 1995) were included. In Latvia, Coleoptera prevailed at one locality whereas Triochoptera dominated at another (Rydell & Petersons 1998).

Critical feeding areas

Woodlands and nearby water bodies, pastures and other open habitats including those within wind parks (Mackie & Racey 2007, Dechmann *et al.* 2014, Roeleke *et al.* 2016).

Commuting routes

In most cases, noctule bats fly directly from the roost to the feeding areas.

Recommendations for conservation and management

- Attention should be paid to the management of areas within 10 km around maternity roosts.
- Conserve broadleaved forest and pastures.
- Practices reducing aquatic and terrestrial insect abundance shall be avoided.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Pipistrellus hanaki (Hanak's Pipistrelle)

Figure 6.22. Pipistrellus hanaki.
© Panagiotis Georgiakakis

Feeding areas

P. hanaki was taxonomically described from material collected in Cyrenaica, Libya (Benda *et al*. 2004). It was discovered very recently in Crete (Hulva *et al*. 2007), which is the only European territory inhabited by this species. Benda *et al*. (2008) described the Cretan populations as a separate subspecies, *P. h. creticus*.

P. hanaki belongs to moderately abundant bat species in Crete and occurs at up to 1,000 m a. s. l. in shrublands, pine forests, olive groves and residential areas (Benda *et al*. 2008). Comparison of feeding habitat preferences with standardised recordings along transects showed that the species' optimum habitat type is mature Mediterranean oak forest (mainly *Q. coccifera*, but also *Q. ilex* and *Q. macrolepis*) which can be found in central and western Crete between 800 and 1,200 m a.s.l. Individual bats forage in a relatively small area (3.1–4.1 km in females, 1.4–3.3 km in males), with most activity concentrated around roosts (Georgiakakis 2009, Georgiakakis *et al.* 2018). *P. hanaki* is relatively abundant in wetlands (rivers, lakes and ponds) which have tree species like *Platanus orientalis* and *Castanea sativa*. The species is also active in winter, although to a considerably lesser extent.

Diet

Not studied.

Critical feeding areas

Oak forests, wooded wetlands, olive and chestnut groves.

Commuting routes

In Crete, *P. hanaki* prefers to roost inside or close to its feeding grounds, therefore commuting is limited (Georgiakakis *et al.* 2018).

Recommendations for conservation and management

- Preservation of old forest stands and tree cultivations.

Pipistrellus kuhlii (Kuhl's pipistrelle)

Figure 6.23. Pipistrellus kuhlii. © Lena Godlevska

Feeding areas

A very flexible and markedly synanthropic species associated with a wide range of landscapes. *P. kuhlii* forages in virtually all habitats below 1,000 m a.s.l., including riparian habitats, forests, farmland and urban settlements (Russo & Jones 2003). It forages frequently in urban areas around street lamps (Haffner & Stutz 1985, Russo & Jones 1999, Rainho 2007), especially near those emitting white light which is more attractive for insect prey. In a Slovak study the pipistrelles preferred an illuminated urban area close to a river in the pre-parturition and post-lactation periods (Maxinová *et al.* 2016).

In Portugal, the species forages in a wide array of habitats, but its activity is greater in wetlands with many trees and in oak woodlands (Rainho 2007). In Crete it is also common in olive groves and inhabited areas. It is not so abundant in shrubland, although this is the most common semi-natural habitat type in Crete (Benda *et al*. 2008, Georgiakakis 2009, Georgiakakis *et al*. 2010).

Diet

Feeds on a variety of taxa, with a preference for Diptera (Whitaker *et al*. 1994; Beck 1995, Feldman *et al*. 2000, Whitaker & Karataş 2009).

Critical feeding areas

Urban und riparian habitats.

Commuting routes

A river bed was used for commuting in Slovakia (Maxinová *et al.* 2016).

Recommendations for conservation and management

- Preservation of riparian habitats and extensive agriculture around settlements, promoting spatial and temporal heterogeneity.
- Reduction of pesticide use.

Pipistrellus nathusii (Nathusius's Pipistrelle)

Figure 6.24. Pipistrellus nathusii. © Lena Godlevska

Feeding areas

P. nathusii is a long distance migratory species (Petersons 2004, Hutterer *et al*. 2005). The species prefers to hunt over water bodies and wetlands. If these are not available, *P. nathusii* forages in richly structured biotopes, *e.g.* along forest edges, tree-lines, roads, old-growth woodlands, sometimes over reeds, pastures or around lamps (Austria: Bauer & Wirth 1979, Spitzenberger 2001, Denmark: Baagøe 2001, Fennoscandia: de Jong 1995, Germany: Heise 1982, Dense 1991, Schmidt 1997, Arnold & Braun 2002, Schorcht *et al*. 2002, Greece: Pieper 1978, von Helversen & Weid 1990, Hanak *et al*. 2001, Italy: Spagnesi *et al*. 2000, Luxembourg: Harbusch *et al*. 2002, the Netherlands: Limpens & Kapteyn 1991, Poland: Ruprecht 1977, 1990, Jarzembowski *et al*. 1998, Ciechanowski 2015, Russia: Chistyakov 2001, Spain and Portugal: Benzal *et al*. 1991, Flaquer *et al*. 2009, Switzerland: Gebhard 1995). In South Caucasus it also forages in semi-desert landscapes (Rakhmatulina 2005).

P. nathusii has a home range of 10–22 km^2 in summer (Schorcht *et al*. 2002). Certain feeding areas may be situated 6.5 km from the roost site. The average size of a foraging area in eastern Germany was 18 ha (Eichstädt 1995), in northern Germany four individual home ranges of females from a maternity colony covered a total area of 5.8 km^2 (Schorcht *et al*. 2002). The common home range of a colony is approximately 80 km^2 (Meschede & Heller 2000, Arnold & Braun 2002).

Diet

It is a typical aerial hawker which hunts mainly on Diptera (Kalko 1995, Beck 1995) but it can also be a facultative gleaner (Pithartová 2007).

Critical feeding areas

Wetlands and riparian habitats (Flaquer *et al*. 2009) and deciduous forests with established nursery colonies.

Commuting routes

The importance of guiding landscape structures, such as coastal lines, great rivers *etc.* is worth mentioning.

Depending on the habitat, commuting routes are generally connected with linear landscape elements, *e.g.* streams, forest edges, hedges, tree-lines and forest roads. However, *P. nathusii* may also commute across open fields (Arnold & Braun 2002).

Recommendations for conservation and management

- Conservation and restoration of wetlands and riparian habitats.
- Maintenance of linear landscape elements, which are important for commuting to feeding areas (hedgerows, tree lines, shrub lines, water streams, drains), within at least 6 km from a maternity roost.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Pipistrellus pipistrellus (Common Pipistrelle)[2]

Figure 6.25. Pipistrellus pipistrellus. © Suren Gazaryan

Feeding areas

Ecological differences between the common pipistrelle (*P. pipistrellus*) and soprano pipistrelle (*P. pygmaeus*) were studied only in recent years, following the recognition of the latter taxon as a distinct species (Barrat *et al*. 1997).

The common pipistrelle is a flexible species that can be found hunting in a wide range of landscapes: from urban centres to arable land and woodland but would hunt close to woodlands or riparian areas, if available (Eichstädt & Bassus 1995, Taake & Vierhaus 2004, Nicholls & Racey 2006a, Nicholls & Racey 2006b, Davidson-Watts *et al.* 2006). As *P. pipistrellus* commonly roosts in buildings, it is mostly found close to human settlements. Heathland, pine woods and sand dunes are poor habitats for the common pipistrelle (Kapteyn 1997). In such habitats it hunts in half-open spaces, *e.g.* under the canopy of trees or along water edges, usually not closer than 1 m to vegetation. Frequently forages around street lamps (Haffner & Stutz 1985, Russo & Jones 1999). In Poland *P. pipistrellus* prefers tree lines in agricultural landscapes as the main foraging habitat and water bodies as the secondary one, avoiding arable land, meadows, mixed and coniferous forests and suburban areas (Ciechanowski 2015).

Distance between feeding areas and roosts can vary, but only females were radio-tracked and seem to forage at the distance around 1.5 km and maximally 5 km from the roost (Helmer 1987, Racey & Swift 1985, Davidson-Watts & Jones 2006, Nicholls & Racey 2006b). In Germany, the average distance between maternity roosts and feeding areas was less than 840 m (Simon *et al*. 2004), and in Scotland it was up to to 1.44 km (Nicholls & Racey 2006b).

[2] Studies before 1997 didn't distinguish between *P. pipistrellus* and *P. pygmaeus.*

Diet

In Europe small Diptera (midges and flies) are preferred (Beck 1995, Barlow 1997, Vaughan 1997, Arlettaz *et al.* 2000, Arnold *et al.* 2003). However, Lepidoptera was the major prey in Turkey (Whitaker & Karataş 2009).

Critical feeding areas

Riparian habitats, traditionally managed farmland and "green areas" in urban settlements such as parks and gardens are important. Riparian areas and woodland edges are favoured (Taake & Vierhaus 2004), but degraded riparian habitats (fewer trees, more uniform bank vegetation, *etc.*) have less bat activity than intact ones (Scott *et al.* 2010).

Commuting routes

P. pipistrellus follows streets, hedgerows, tree lines or woodland edges for commuting and crosses open spaces of up to a few hundred metres in a direct flight (Helmer 1987, Verboom & Huitema 1997, Simon *et al.* 2004).

Recommendations for conservation and management

- Preservation and restoration of riparian habitats and low-intensity agriculture, promoting spatial and temporal heterogeneity.
- Reduction of pesticide use.
- Establishment and appropriate management of gardens and parks in built-up areas.
- Avoidance and mitigation programme must be implemented in wind farm projects.

Pipistrellus pygmaeus (Soprano Pipistrelle)

Figure 6.26. Pipistrellus pygmaeus. © Lena Godlevska

Feeding areas

Several studies in the British Isles (Vaughan *et al.* 1997, Russ & Montgomery 2002, Nicholls & Racey 2006 a, b) concluded that *P. pygmaeus* utilises a narrower feeding niche than *P. pipistrellus*, foraging mainly over or near wetlands (rivers, canals, lake/reservoir margins and riparian woodland). This was also suggested by studies based on faecal analysis of the two phonic types (Barlow 1997). However, Glendell & Vaughan (2002) found that soprano pipistrelles selected tree lines and semi-natural woodlands over aquatic habitats in landscape parks in England, and Russ & Montgomery (2002) found that not only wetlands but also deciduous woodland was significantly selected in Northern Ireland. In northern Poland, it selected lakes and ponds and roads in broadleaf forests (Ciechanowski 2015). Bartonička & Ȩehák (2004) found a particularly high flight activity over water during spring, and an increase in foraging activity in ecotones and forest glades later in the season in their study area in Moravia, Czechia. Non-aquatic Brachycera were found in the diet particularly in the second half of the year (Arnold *et al*. 2003). In Scandinavia, where the soprano pipistrelle is by far the most widespread and numerous of the two species, *P. pygmaeus* does not show the same strong association with wetland habitats but also hunts in woodland clearings, along tree lines and at forest edges and in parks and gardens with stands of deciduous trees (Ahlén 2004, Baagøe 2007). Wetlands also constitute important hunting habitats, perhaps particularly in areas with otherwise low insect production (Ahlén 2004). In Portugal, the species uses the same habitats as *P. kuhlii* including water sites, oak woodlands and urban areas (Rainho 2007).

In Scotland, soprano pipistrelles travelled an average 0.7 km to the feeding area (Nicholls & Racey 2006b), whereas in another study they foraged an average of *c*. 1.5 km from the roost (Stone *et al.* 2015).

In South East England the hunting activity of *P. pygmaeus* along river stretches polluted by sewage outputs was lower than along cleaner river stretches. However, its activity was less affected than that of *P. pipistrellus* (Vaughan *et al.* 1997).

Diet

Barlow (1997) found that *P. pygmaeus* mainly feeds on pollution-tolerant prey associated with wetland habitats in Britain. Small Diptera (midges and flies), followed by Hymenoptera (ichneumonid wasps), Homoptera (aphids and cicadas) and Planipennia (lacewings) were preferred by both *P. pygmaeus* and *P. pipistrellus* in Heidelberg forest, Germany (Arnold *et al*. 2003). In Czechia, half of the diet consisted of Chironomidae/Ceratopogonidae. The diet also contained Diptera/Brachycera, Sternorrhyncha, Culicidae and Hymenoptera (Pithartová 2007).

Critical feeding areas

Riparian habitats and woodlands.

Commuting routes

Linear landscape elements are likely to be important for this species, as they are for common pipistrelles (*e.g.* Verboom & Huitema 1997).

Recommendations for conservation and management

- Conservation and restoration of wetlands and mature deciduous forests around maternity colonies.
- Preservation of linear landscape elements like hedgerows, tree lines and waterways with bankside vegetation.

Hypsugo savii (Savi's Pipistrelle)

Figure 6.27. Hypsugo savii. © Suren Gazaryan

Feeding areas

H. savii is associated with a wide range of landscapes and is markedly synanthropic. It may be observed feeding in many habitats, including riparian habitats, forest edges, farmland and urban settlements (Russo & Jones 2003) also in mountainous areas over 1,000 m a.s.l. In Northern Italy it mainly uses water habitats (Toffoli 2007). In southern Italy it also forages in artificial conifer plantations and frequently hunts around street lamps, especially those emitting white light which are more attractive for insect prey (Russo & Jones 2003). In Crete it forages mainly in oak forests and wetlands (rivers, lakes and ponds). It is also present in shrublands up to 1,800 m a.s.l. Its feeding activity during winter is minimal (Benda *et al*. 2008, Georgiakakis 2009).

Diet

In Germany, it hunted mainly on Lepidoptera, Diptera, Hymenoptera and Neuroptera (Beck 1995). According to Horáček & Benda (2004), main prey components were Homoptera, Heteroptera and Lepidoptera in Europe. In Turkey, Formicidae and Coleoptera constituted major prey items (Whitaker & Karataş 2009).

Critical feeding areas

Riparian habitats, traditionally managed farmland and "green areas" in urban settlements such as parks and gardens may be especially important. Oak forests, wooded wetlands and chestnut groves are important in Crete.

Commuting routes

May follow landscape structures or commute directly to feeding areas.

Recommendations for conservation and management

- Preservation of riparian habitats and low-intensity agriculture, promoting spatial and temporal heterogeneity.
- Reduction of pesticide use.
- Establishment and appropriate management of gardens and parks in built-up areas.
- Native broadleaved tree species are preferable for reforestation.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Eptesicus isabellinus (Isabelline Serotine)

Figure 6.28. Eptesicus isabellinus. © Francisco Amorim

Feeding areas

In Algeria *E. isabellinus* is a typical air hunter but can sometimes capture prey on "surfaces" (rocks, leaves) as it often flys near vegetation and bare rocks (Gaisler & Kowalski 1986). In Europe, *E. isabellinus* differs from the closely related *E. serotinus* by occurring in xeric habitats (Santos *et al.* 2014). In Spain, colonies are located either in the irrigated agricultural or Mediterranean shrub landscapes (Papadatou *et al.* 2011). *E. isabellinus* selects areas with high relative humidity (*e.g.* river banks) as preferred hunting sites, most probably because of the highest availability of hard insects, such as Coleoptera and Hemiptera, which represent the majority of its diet (Pérez-Jordá 1994). In Murcia, they also show high affinity to streams and less often to matorrals, avoiding crops (Lisón *et al.* 2014). In central Tunisia, *E. isabellinus* preferentially hunts in areas where water bodies (streams, water tanks) are surrounded by vegetation (Dalhoumi *et al.* 2017).

Diet

Relatively diverse, including Diptera and Dermaptera, Coleoptera, Hemiptera and Lepidoptera (Lisón *et al.* 2015) and in Lybia even Hymenoptera (Formicoidea) (Benda *et al.* 2014).

Critical feeding areas

Insect-rich wetlands.

Commuting routes

Not studied.

Recommendations for conservation and management

- Support the abundance and diversity of prey by ensuring the quality of aquatic environments.
- Protect, preserve and restore matorrals and wetlands.

Eptesicus nilssonii (Northern Bat)

Figure 6.29. Eptesicus nilssonii. © Jens Rydell

Feeding areas

E. nilssonii is opportunistic in its foraging behavior (Haupt *et al.* 2006, Wermundsen & Siivonen 2008). Feeding areas include farmland and forests, where they fly in open spaces like forest glades and clearings. They feed at forest edges and tree lines and over water and along riverside tree stands, also in urban parks and suburban gardens.

The flight path while hunting is typically straight or slightly curved at a height of 5–10 m, with a range of 2–50 m (Rydell 1992b). Females often establish small feeding territories of approximately 100 m^2 in places where insects are abundant, which are used by the same individual night after night (Rydell 1986b, 1992b).

Females mostly hunt within 600 m of the colony over lakes and wetlands. When insect density decreases they may shift to hunting sites up to 4–5 km from the colony. After weaning they can fly more than 30 km to visit deciduous woodlands and eutrophic lakes (de Jong 1995). In Lower Saxony, Germany, forest habitats were used opportunistically before the birth of the young and avoided thereafter in favour of urban habitats with streetlamps (Haupt *et al.* 2006). In Norway, Frafjord (2013) observed a significant increase in the home range size of female bats as the season progressed. In Lower Saxony males moved up to 70 km per night in exploration flights (Haupt *et al.* 2006). In the spring and late summer/autumn the northern bats often hunt near artificial light sources (Rydell 1991, 1992b).

Diet

E. nilssonii preys upon Diptera, mainly Chironomidae and Tipulidae, Coleoptera, Ephemeroptera and Trichoptera (Rydell 1986a, 1989). The diet was different in Moravia where Lepidoptera, Heteroptera, Homoptera and Diptera, mainly Brachycera dominated (Gajdošik & Gaisler 2004).

Critical feeding areas

Water bodies, beaver flowages, deciduous forests near water and other areas with high insect abundance within 5 km of colonies are important for lactating females, particularly in regions with otherwise low insect production (de Jong & Ahlén 1991, de Jong 1995, Nummi *et al.* 2011).

Commuting routes

Linear landscape elements are relatively unimportant since northern bats often take the shortest route between hunting sites or between roosts and hunting sites (de Jong 1995).

Recommendations for conservation and management

- Attention should be paid especially to management of areas with high insect production within 5 km from maternity colonies.
- Natural forests and grasslands remain essential, at least in some part of the range.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Eptesicus serotinus (Common Serotine)

Figure 6.30. Eptesicus serotinus. © Lena Godlevska

Feeding areas

E. serotinus is an edge and open-area specialist. It can glean insects from vegetation or the ground but the predominant foraging strategy is aerial hawking (Baagøe 2001). It usually forages around and in the canopy of trees (Kurtze 1991). In open pastures, it can fly close to the ground or up to 20 m with sudden steep dives. The species often feeds along roads and around street lamps (Baagøe 2001, Ciechanowski 2015). However, it used no anthropogenic habitats in Switzerland (Mattei-Roesli *et al.* 2008). Serotine bats select their feeding areas according to the availability of prey. Main prey taxa are associated with semi-open and open habitats such as meadows and pastures with tree groups, hedges or woodland edges (Harbusch 2003).

The distance to foraging sites can reach 5–7 km, but usually serotines spend around 90% of their foraging time at distances smaller than 2 km from the maternity roost. A high percentage of traditional feeding sites is used by the colonies in subsequent years (Catto *et al.* 1996, Kervyn *et al.* 1997, Kervyn 2001, Harbusch 2003).

Diet

Faecal analyses of the serotine bat in different parts of its European range revealed predominantly Coleoptera (*e.g. Aphodius*, Melolonthinae, *Necrophorus*), Lepidoptera, Diptera, Trichoptera, Hemiptera and Hymenoptera (Kurtze 1982, Labee & Voûte 1983, Robinson & Stebbings 1993, Catto *et al.* 1994, Beck 1995, Gerber *et al.* 1996, Vaughan 1997, Kervyn 2001, Gajdošik & Gaisler 2004, Beck *et al.* 2006, Kervyn & Libois 2008, Zukal & Gajdošik 2012, Mikula & Čmoková 2012).

Critical feeding areas

The most important feeding areas are those within 2 km of maternity roosts. These are usually unimproved pastures with tree groups or hedgerows, as well as deciduous woodlands in a mosaic with grassland. In Germany, the average distance between maternity roosts and feeding areas was approximately 1 km (Simon *et al.* 2004).

Commuting routes

E. serotinus can fly straight to the feeding areas. However, these bats can opportunistically use available linear landscape elements.

Recommendations for conservation and management

- Conservation of permanent and extensively-used pastures within 2 km of maternity roosts.
- Park-like landscape structures such as tree groups within grassland or extensively-farmed orchards should be preserved and created.

- The use of insecticides within feeding areas shall be avoided.
- Broadleaf woodlands, especially those close to maternity colonies, should be conserved and promoted.
- Woodland borders adjacent to grassland should include a broad range of shrubs.
- The use of anti-parasitic drugs on cattle close to the maternity roost should be avoided from the early spring through to the autumn.
- Local planning of green spaces within settlement areas should promote unbuilt areas such as gardens, parks or fallow land.
- Avoidance and mitigation programme must be implemented in wind farm projects.

Vespertilio murinus (Parti-colored Bat)

Figure 6.31. Vespertilio murinus. © Lena Godlevska

Feeding areas

V. murinus hunts in a variety of habitats, *e.g.* over water, open agricultural areas, steppe, meadows, riparian zones, forested areas and human settlements (Rydell & Baagøe 1994, Baagøe 2001). A mosaic of habitat types appears to be important. In Mecklenburg-Vorpommern, Germany and Eastern Poland the surroundings of roosts contained larger wetlands with slow flowing or static water and extensive forest areas, if compared to random sites (Hermanns *et al.* 2001). Numerous (200+) male colonies also occur. Colonies are mostly situated in buildings (Rydell & Baagøe 1994, Baagøe 2001). While hunting, this species usually flies 20–40 m above the ground (Rydell & Baagøe 1994) and around street lights (Rydell 1992a, Rydell & Racey 1995).

Jaberg *et al.* (1998) radiotracked females from a breeding colony in Switzerland between May and July and found that the bats were hunting exclusively above shallow places and natural shores of a large lake and avoided other landscape features. Jaberg & Blant (2003) examined the spatial distribution of maternity and male roosts in relation to foraging habitats. The day roosts were situated at an average distance of 1.06 ± 0.69 km from the shore of a large lake. For night roosting, the bats mainly used trees in a riparian forest within a few hundred metres from either the nursery roost or feeding areas.

Safi (2006) found that males foraged within an average home range of 86 km^2 without returning to the roost. On the other hand, females frequently returned to the roost and had a smaller average home range of 16 km^2.

Males exploited open agricultural landscape and forests, as well as rivers, as main feeding areas, whereas females almost exclusively foraged above lakes (Safi *et al.* 2007).

Diet

Chironomidae are the main prey in Europe (Rydell 1992a, Beck 1995, Jaberg et al. 1998).

Critical feeding areas

Bodies of water are important for females in the summer, while males are more flexible in their foraging habits. A landscape mosaic of water bodies/wetlands and deciduous forests was reported within 2–3 km radius of maternity roosts (Jaberg *et al.* 1998, Hermanns *et al.* 2001, Jaberg & Blant 2003, Safi 2006).

Commuting routes

V. murinus commutes directly to the feeding areas.

Recommendations for conservation and management

- Maintenance of areas with high insect biomass within a distance of 5 km from maternity colonies.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Miniopterus schreibersii (Schreiber's Bent-winged Bat)

Figure 6.32. Miniopterus schreibersii. © Suren Gazaryan

Feeding areas

M. schreibersii forages mainly in deciduous woodlands and mature orchards (including olive groves), gardens, along hedgerows separating pastures and riverine forests and in urban areas (Barataud 1992, Lugon & Roué 1999a, Russo & Jones 2003, Rainho 2007, Vincent 2007, Némoz & Brisorgueil 2008, Roué 2008, Rainho & Palmeirim 2011). In the Mediterranean area they can use grasslands (Barataud) but avoid arable land and maquis (Russo & Jones 2003). However, in Portugal they use farmland (olive and cereals), avoiding montado with denser tree cover (Rainho 2011, Rainho & Palmeirim 2013) and favouring areas close to the roost (Rainho & Palmeirim 2011). In some populations pregnant and lactating females forage over white street-lamps (Némoz *et al.* 2007, Vincent 2007, Némoz & Brisorgueil 2008, Roué 2008, Rainho 2011, Vincent *et al.* 2011).

In France feeding areas are commonly located within 30 km of the main roost (Roué 2008, Vincent *et al.* 2011). In Portugal 82 % of females forage within 10 km of the colony (Rainho 2011). In France, each female foraged over an area of 18.5 ha in Franche-Comté (Roué 2008), 7.5 ha in the Rhône Valley (Vincent 2007). Females moved from one good feeding area to another during the night: from 3 patches within a 500 m radius of a roost to up to 6 patches 4 km away (Vincent 2007, Némoz & Brisorgueil 2008, Vincent *et al.* 2011). Females demonstrated fidelity to feeding areas over at least short periods, whereas juveniles changed their feeding areas every night (Guillaume & Roué 2006, Némoz & Brisorgueil 2008). Lactating females foraged farther than pregnant females. Their home range was 22,318 ± 7,141 ha vs. 10,837 ± 5,399 ha in the Rhône

Valley (Némoz *et al.* 2007, Vincent *et al.* 2011). The foraging area of maternity colonies was *c.* 200,000 ha (Némoz & Brisorgueil 2008, Roué 2008, Vincent *et al.* 2011).

Diet

Lepidoptera dominated in the diet in all seasons and comprised 76–95 % of the volume (Lugon & Roué 1999a, Presetnik 2002, 2005, Lugon 2006, Presetnik & Aulagnier 2013). Diptera (mainly Tipulidae in late summer) was the second main prey in France (Lugon & Roué 1999b, Roué 2002) versus Neuroptera in Slovenia (Presetnik 2002, 2005, Presetnik & Aulagnier 2013). Prey included larvae of Lepidoptera and Aranaeidea, as well as taxa flying close to vegetation *(Mycetophilidae, Tipulidae and Cyclorraphae)* (Lugon & Roué 1999a). According to a DNA barcoding study, Geometridae and Noctuidae were the most represented families of the lepidopterans. Dipterans were the second most consumed prey. Several taxa of Coleoptera, Neuroptera, Orthoptera and Trichoptera were also recorded. Prey also included many pest arthropod species (Aizpurua *et al.* 2018).

Critical feeding areas

Deciduous woodlands, mature orchards, riverine forests and hedgerows with high Lepidoptera production.

Commuting routes

M. schreibersii uses treelines, woodland borders, forest paths, hedgerows and riverine forests as commuting routes, flying usually at an altitude of 5–10 m and at 2 m from the vegetation. However they can fly closer to the ground when crossing open spaces which are less than 300 m wide (Constant 1957, Barataud 1992, Lugon & Roué 2002). Despite their quick flight (50–54 km/h, Constant & Cannonge 1957) they can easily fly over obstacles, including linear infrastructures (Lugon & Roué 2002). They use rivers as landmarks when commuting (Serra-Cobo *et al.* 2000, Russo & Jones 2003) and also when they are migrating (Serra-Cobo *et al.* 1998).

Recommendations for conservation and management

- Conservation management of areas within at least 30 km of the nursing roosts.
- Treelines, mixed deciduous woodlands and riverine forests shall be preserved and replanted.
- Vary forest logging, conserve borders.
- The use of insecticides should be prohibited in forests.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Tadarida teniotis (European Free-tailed Bat)

Figure 6.33. Tadarida teniotis. © Jens Rydell

Feeding habitats and areas

T. teniotis is a generalist aerial-hawker that forages above forested areas, meadows, streetlights *etc.* It hunts where it finds swarms of insects and therefore exploits various habitats: stone pine and/or cork oak woodlands, mountain forests, orchards, annual crops, scrublands, lakes and illuminated urban areas (Arlettaz 1990). In Italy the species shows no particular habitat preference (Russo & Jones 2003). In Portugal it shows lower activity over fresh-water habitats (Rainho 2007).

To find a suitable feeding area, it can fly up to 36 km from the roost. The size of feeding areas is approximately 102 ha (Marques *et al*. 2004).

Diet

Rydell & Arlettaz (1994) reported that Lepidoptera constitute 68.3 % of the diet at a locality in France (along with 24.3 % Neuroptera) and 86.8 % in Kirghizstan. In Turkey, however, it was classed as a gryllid or gryllid/coleopteran feeder (Whitaker & Karataş 2009). In northeast Portugal, moths (Lepidoptera; mainly Noctuidae and Geometridae) were by far the most frequently recorded prey. Significant dietary differences between males and females, irrespective of age and season were recorded. Females consumed larger moths and more moths of migratory species (Mata *et al.* 2016).

Critical feeding areas

All types of habitats which are rich in insects.

Commuting routes

T. teniotis commutes directly to feeding areas.

Recommendations for conservation and management

- Maintain and increase insect abundance.
- Avoidance and mitigation programmes must be implemented in wind farm projects.

Plecotus auritus (Brown Long-eared Bat)

Figure 6.34. Plecotus auritus. © Suren Gazaryan

Feeding areas

P. auritus is a woodland bat, that gleans sitting prey and catches it in flight (Rydell 1989, Meineke 1991, Swift 1998). Its foraging habitats are woodlands, forest edges, bushes, hedges, traditional orchards, parks and gardens (Horáček 1975, Fuhrmann & Seitz 1992, Entwistle *et al*. 1996, Swift 1998, Kiefer & Boye 2004, Kyheröinen 2008, Ashrafi *et al.* 2013). Ekman & de Jong (1996) found that the species did not forage in patches of isolated woodland in open agricultural areas.

In Switzerland, the mean foraging distance from the roost was 1.2 ± 0.6 km and the mean home ranges were 51.8 ± 33.8 ha (5.2 – 103.2 ha) (Ashrafi *et al.* 2013).

Diet

In Germany, Lepidoptera and Diptera were almost equally represented in the diet (Beck 1995). In Switzerland 41.0 % of the prey volume was Lepidoptera, followed by Coleoptera, Diptera, Dermaptera, Arachnida and Chilopoda (Ashrafi *et al.* 2011). In the UK, Lepidoptera made up 64.7 % of the diet (Razgour *et al.* 2011b). Lepidopteran prey also prevailed according to a Finnish study but ~ 20 % of the diet (in terms of relative abundance) were Coleoptera, particularly ground beetles (Vesterinen *et al.* 2018).

Critical feeding areas

Important habitats are woodlands, parks and gardens (Fuhrmann & Seitz 1992, Entwistle *et al.* 1996, Swift 1998, Kyheröinen 2008, Ashrafi *et al.* 2013).

Commuting routes

Hedgerows, tree lines, fences and river edges can be used as commuting routes (Barataud 1990, Entwistle *et al.* 1996, Swift 1998, Kyheröinen 2008).

Recommendations for conservation and management

- Protection and restoration of woodlands, orchards and gardens within 1.5 km of roosts.
- Preservation and creation of linear landscape elements like hedgerows and alleys around roosts.
- Avoidance of light trespass.

Plecotus austriacus (Grey Long-eared Bat)

Figure 6.35. Plecotus austriacus. © Andreas Zahn

Feeding areas

P. austriacus forages above meadows, uncultivated fields, unimproved meadows, marshes, in open forests and at forest edges and in more urbanised areas, such as orchards and parks. It avoids arable fields, conifer woods and open water (Horáček 1975, Flückinger & Beck 1995, Swift 1998, Kiefer & Veith 1998, Boeckx 2005, Ashrafi *et al.* 2013). In the country grey long-eared bats use more natural habitats like field margins, hedges and scattered trees (Razgour *et al.* 2011a).

The species usually hunts in feeding areas close to the roost but can sometimes forage up to 5.5 km away (Kiefer & Veith 1998, Flückinger & Beck 1995, Boeckx 2005, Razgour *et al.* 2011a).

According to Razgour *et al.* (2013) home range sizes in England are highly variable, with lactating females having the largest mean home ranges of 460 ± 300 ha (30–870 ha). Colony range size varies between locations (1,740–37,200 ha). In Switzerland, the mean foraging distance from the roost was

2.9 ± 1.5 km and the home range 295.5 ± 296 ha (12.9–804.0 ha) (Ashrafi *et al.* 2013).

Diet

The most common prey components are Lepidoptera, followed by Diptera (Barataud 1990, Meineke 1991, Beck 1995, Swift 1998, Razgour *et al.* 2013). Lepidoptera composed 66.7 % of the diet in the UK (Razgour *et al.* 2011b) and 87.0 % in Switzerland (Ashrafi *et al.* 2011).

Critical feeding areas

Grasslands, marshes, open woodlands, orchards, parks and gardens.

Commuting routes

Linear landscape elements such as hedges, tree lines, fences, banks and streams or even railway lines. This species can also cross open meadows in fast and low flight (Barataud 1990, Swift 1998, Ashrafi *et al.* 2013).

Recommendations for conservation and management

- Conserve woodlands, traditional orchards and extensive farmlands within home ranges of females (up to 5 km around maternity roosts).
- Avoid pesticide use within feeding areas.
- Increase the availability and quality of riparian habitats.
- Manage hedgerows to increase mature broadleaf tree cover, in particular around riparian elements like streams and ditches.
- Avoid light trespass.

Plecotus macrobullaris (Alpine Long-eared Bat)

Figure 6.36. Plecotus macrobullaris. © Suren Gazaryan

Feeding areas

In Italy, *P. macrobullaris* favoured ecotones and rural areas (villages) and avoided woods. The mean foraging distance was around 1 km (1.1 ± 1.5 km). For individual bats, the shortest distance from the roost was 260 m and the longest 2,265 m. Overall, more than 50 % of tagged bats were detected within 500 m from the roost and about 75 % within 1 km. Nevertheless, several bats regularly commuted to foraging sites situated more than 2–3 km of the roost, with the maximum distance being 7.1 km (Preatoni *et al.* 2011).

In Switzerland, *P. macrobullaris* preferred deciduous forests and grasslands. The mean foraging distance from the roost was 2.5 ± 1.6 km and the home range was 239.5 ± 284 ha (64–797 ha). The maximum observed distance from the roost was 4.6 km (Ashrafi *et al.* 2013).

Diet

In Turkey, moths constituted 90 % vol. of the diet (Whitaker & Karataş 2009). In Switzerland, Lepidoptera also dominated (mean 88.0%, range: 82.0–93.0%), followed by Coleoptera (3.5%, 1.2–7.9%) and Diptera (6.7%, 3.8–9.0%). That was confirmed by DNA mini-barcoding in Spain that revealed 97.8% of moths in the diet (Alberdi *et al.* 2012).

Critical feeding areas

Grasslands, including intensively managed ones and deciduous forests.

Commuting routes

Observed commuting flights were direct, almost straight-line movements (Preatoni *et al.* 2011, Ashrafi *et al.* 2013).

Recommendations for conservation and management

- Conserve woodlands, traditional orchards and extensively used farmlands within home ranges of females, up to 5 km around maternity roosts.
- Avoid pesticide use within feeding areas.
- Increase the availability and quality of riparian habitats.
- Manage hedgerows to increase mature broadleaf tree cover, in particular around riparian elements like streams and ditches.
- Avoid light trespass.

Barbastella barbastellus (Western Barbastelle)

Figure 6.37. Barbastellus barbastellus. © Andreas Zahn

Feeding areas

Whereas a mature forest is an important foraging habitat for this woodland bat (Sierro & Arlettaz 1997, Sierro 1999, Rebelo *et al.* 2012), vegetation edges, mosaics and riparian zones are also frequently selected for foraging (Russ 1999, Zeale *et al.* 2012). In forests it forages above the canopy, c. 2–4 m above tree crowns (Sierro & Arlettaz 1997), but may also forage below it, along forest trails and roads, as well as in forest gaps (Roué & Barataud 1999, D. Russo, pers. obs.). In a German study, it was ascertained that foraging sites have a much greater proportion of forest and more structural variety than random ones (Simon *et al.* 2004). In the absence of woods in central Italy barbastelles foraged in non-forest habitats and alongside a riparian vegetation (Ancillotto *et al.* 2014).

Barbastelles may cover long distances in short times. In the UK, foraging sites have been recorded at more than 25 km from roosting areas (Girard-Claudon 2011, Zeale *et al.* 2012, Vernet *et al.* 2014). Even 4-week old juveniles may fly 7 km from their roosts (Warren 2008). Individual home ranges recorded in Switzerland averaged 8.8 ha, but were much wider in Germany: 125–2,551 ha (median: 403 ha), with core areas (1–5 per individual) being 5–285 ha (mean 67 ha) (Hillen *et al*. 2009). In south-eastern France the home ranges were even wider: mean 1,220 ± 1,600 ha, maximum 8,600 ha (Girard-Claudon 2011, Vernet *et al.* 2014).

The home ranges of tracked male barbastelles in Germany were smaller (88–864 ha) than those of females (125–2,551 ha, Hillen *et al.* 2011).

Diet

Feeds mainly on small moths (Beck 1995, Rydell *et al.* 1996, Sierro & Arlettaz 1997, Vaughan 1997, Sierro 2003, Andreas *et al.* 2012).

Critical feeding areas

Richly structured mature forests and wooded riparian valleys.

Commuting routes

Although it may cross open areas, forest corridors (*e.g.* forest roads) and forest edges are important commuting landmarks. It prefers using underpasses when crossing roads (Kerth & Melber 2009).

Recommendations for conservation and management

- Large areas of highly structured forest should be preserved.
- Unmanaged forest patches with numerous dead trees should be retained.
- Tall riparian vegetation should be carefully preserved.
- Forest continuity should be favoured by promoting corridors connecting networks of important sites.
- Pay attention to the management of foraging sites within at least 10 km of the main roosting areas.
- High underpasses should take precedence over other mitigation methods during road construction.
- Preserve small ponds, cattle troughs and other water bodies in forests and along their edges.

Otonycteris hemprichii (Hemprich's Long-eared Bat)

Figure 6.38. Otonycteris hemprichii. © Jens Rydell

Feeding areas

Otonycteris hemprichii usually forages over rocky habitats with sparse herb vegetation, hovering close to the ground (Korine & Pinshow 2004). They also forage over small ponds in arid zones with many rock crevices (Harrison & Bates 1991, Bates & Harrison 1997), wadis and areas with spring vegetation and even over a garbage dump (Yom-Tov 1993, Fenton *et al.* 1999).

When feeding areas are next to the roost (0.5–2 km), females performed 3–4 foraging bouts per night versus only one in the case where the roost was 9 km away (Daniel *et al*. 2008). This pattern is altered by pregnancy and nursing (Daniel *et al.* 2010).

Diet

Depending on the feeding areas, the diet varies seasonally and prey is taken from the ground and on the wing (Fenton *et al.* 1999). The diverse diet includes Scarabeidae, Chilopoda, Heteroptera, Hymenoptera, Diptera, Coleoptera, Araneida, Scorpionida, Solifugae and Acrididae (Whitaker *et al*. 1994, Fenton *et al.* 1999, Benda *et al.* 2006, 2008, 2010, Holderied *et al*. 2010).

Critical feeding areas

Insect-rich areas near bodies of water are the most favourable.

Commuting routes

Hemprich's long-eared bats fly straight to feeding areas over rocky habitats (Daniel *et al.* 2008).

Recommendations for conservation and management

Maintenance and creation of water bodies.

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EUROBATS

Until recently, much conservation efforts have focused on protecting bat roosting sites, most vulnerable to disturbance, exclusion or persecution. EUROBATS has already published guidance on the conservation and management of underground roosts (caves, abandoned mines, bunkers, *etc.*) and overground roosting sites (such as buildings of cultural heritage).

However, protecting bat roosts alone is not enough to ensure favourable trends in bat populations. Outside the roost, bats need suitable habitats where they can hunt and find sufficient food of the right sort, as well as routes that allow them to travel between roosts and feeding areas. In the past very little was known about activities of bats outside the roost, but this knowledge gap has narrowed down dramatically with the development of bat detectors and, especially, with radio-tracking studies. These research methods have allowed scientists to follow bats from their roosts, determining how far they fly and which types of habitats they prefer for hunting. Our knowledge of the needs and habits of individual species is constantly increasing and certain recommendations on the conservation and management of feeding areas and commuting routes have already been developed.

Therefore, EUROBATS Resolution 4.9 urges Parties to take the conservation of bat habitats into consideration and draft national guidelines for this purpose. The Advisory Committee was tasked with preparing a general guidance for the use of Parties for this purpose. Subsequently, a working group on Conservation and Management of Critical Feeding Areas, Core Areas around Colonies and Commuting Routes was convened for drafting this guidance document. Resolution 7.9 reiterates the importance of critical feeding areas and commuting routes, and urges Parties to take them into account in land use and planning decisions, based on the generic EUROBATS guidance.

This guidance, which draws on the latest scientific information on each European species, should help in considering bat habitats during various land-management activities and thus make a positive contribution to their conservation. It should also help regulatory authorities to ensure that agriculture, forest management regulations and support schemes are designed in such a way as to ensure the conservation of these protected species. As this guidance is intended to cover the entire EUROBATS range, supplementing it with national guidance is highly encouraged. National or regional guidelines can better take local farming and forest management practices into account and ensure that the guidance is locally relevant.

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