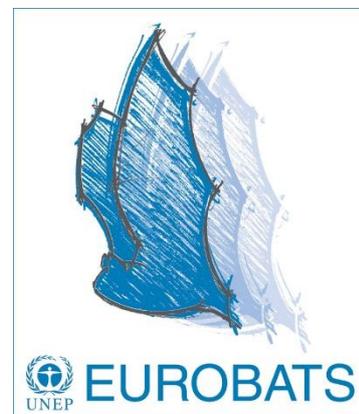


## 24<sup>th</sup> Meeting of the Advisory Committee

Skopje, North Macedonia, 1 – 3 April 2019

### Report of the Intersessional Working Group on the Impact of Roads and other Traffic Infrastructure on Bats



A draft of the EUROBATS guidelines on the effects of roads and other traffic infrastructure (Annex 1) has been prepared for circulation at the meeting by Jean Matthews (Convenor), Branko Karapandža and Dr. Jasja Dekker and Primož Presetnik. The Convenor is grateful for offers to provide comments on specific parts of the text from Lothar Bach, Hermann Limpens, Fabien Claireau and Charlotte Roemer. The List of bat species recorded as casualties of traffic (all types) in the EUROBATS region has also been updated (see Annex 2).

The Convenor is not able to attend the meeting but welcomes comments, additional information and offers of assistance in completing the publication in order to complete the publication in the next few months. Please provide any comments or additional information by 30<sup>th</sup> April.

Information is lacking for two particular aspects – firstly, any additional information on the potential impact of air traffic is welcomed. Secondly, as most research on roads and railways has been done in northern and western Europe, details of any studies relating to roads or rail in eastern and southern states would be helpful.

Eurobats Publication “*The impact on bats of roads and other traffic infrastructure*”  
 Draft to send out v 3124 Mar 2019 (See also additional notes)

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## Foreword

The Intersessional Working Group (IWG) on the Impact of Roads and other Traffic Infrastructures on Bats was established at the 12<sup>th</sup> EUROBATS Advisory Committee (AC) Meeting in Budapest, Hungary, 7 – 8 May 2007.

In 2010, the 6<sup>th</sup> EUROBATS Meeting of Parties, Prague, Czech Republic 20 – 22 September 2010 (MoP 6) requested the Advisory Committee (AC) to develop and publish a EUROBATS booklet highlighting the effects of roads on bats and providing guidance on minimising the impact of traffic infrastructure projects on bats. Resolution 7.9 was passed at the 7<sup>th</sup> (MoP 7) in Brussels, Belgium 15 – 17 September, 2014. This urges Parties and non-party Range States to:

1. Take bats into account during the planning, construction and operation of roads and other infrastructure projects;
2. Ensure that pre-construction strategic and environmental impacts assessment procedures and post-construction monitoring are undertaken and recommend that the data collected are made available for independent scientific analysis;
3. Promote further research into the impact of new and existing roads and other infrastructure on bats and into the effectiveness of mitigation measures;
4. Develop appropriate national or supranational guidelines, drawing on the general guidance to be published by the Advisory Committee.

## 1. Introduction

### 1.1 Scope and structure of this guidance document

These guidelines have been produced by the Intersessional Working Group on the Impact of Roads and Other Traffic Infrastructures on Bats, part of the EUROBATS Advisory Committee to meet the request under Resolution 7.9. They provide a basis for EUROBATS’ Range States to produce their own national guidance taking into account such factors as the composition and ecology of bat species, the topography, climate and construction, legislation and planning regimes in their locality.

The document is aimed particularly at those involved in taking decisions about traffic infrastructure that may impact on bats, including infrastructure planning and design, bat surveys, impact assessment, designing and monitoring mitigation, compensation and enhancement. It is relevant to all road projects, be they new construction, improvement or maintenance projects. The guidance will need to be interpreted through other relevant protocols for activities such as tree surveys, structural inspections and management of the highways estate.

It is important to note that “guidelines are only guidelines” and no particular method or solution will be appropriate or proportionate in every instance. Advice should be sought from qualified specialists and agreed with the relevant advisors on a site-specific basis.

Our understanding of the effects of roads and other developments on bats and of the effectiveness of mitigation techniques has increased significantly in recent years, although is still subject to uncertainty; current research projects and innovations in technology mean that it will continue to change. The information in this document is considered to be accurate at the time of publication, but will need to be reviewed and updated as new information comes to light.

The decision-making processes for different types of major infrastructure projects have much in common. It is the intention of this document to focus on issues associated with transport projects, both construction and operation, rather than on generic issues associated with large infrastructure projects. Information on sources of guidance on generic issues is provided.

Most research on the impacts on bats of transport infrastructure has been carried out in relation to roads. There is limited information on the impact of other traffic infrastructures, such as rail and air transport. Where issues have been identified that are specific to air or rail infrastructure projects these are noted within the relevant section or considered in Chapter 7.

Some examples are given within the text but there is also a section on Case Studies in Annex X.

Technical terms and abbreviations (highlighted in bold and italics) are explained in the Glossary.

### 1.2 Legislative background

Most EUROBATS range states have some form of national legislation protecting bats from killing, injury and disturbance and from damage or destruction of roosts, although a small number do not. Enforcement of regulations varies greatly between countries.

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Bats are reliant on large areas of habitat containing a range of roost sites for different life stages and in different seasons and including foraging grounds and commuting routes allowing them to move between them. Most legislation focusses on protecting bats from deliberate acts resulting in direct injury or killing, or destruction of roost sites. Protection of wider habitats is generally more limited.

**1.2.1 The EU Habitats Directive (92/43/EEC)**<sup>1</sup>. Specific legislation applies to Member States of the European Union as all microchiroptera species are listed on Annex IV of the Directive. This requires Member States to take measures to establish a system of strict protection for these species in their natural range. In addition the rarest species are also listed on Annex II as species of community interest for which Special Areas of Conservation (SACs) are to be designated. Under Article 6 (3) and (4), schemes that may significantly affect SACs require additional consideration, including a greater level of survey intensity and a higher level of confidence in the effectiveness of any proposed mitigation (EC, 2002)<sup>2</sup>.

Under Article 12 (4) there is a requirement for Member States to monitor the impact of incidental killing of bats and take further research and conservation measures to ensure that this does not have a significant impact on the species concerned.

**1.2.2 The Convention on the Conservation of Migratory Species of Wild Animals, 1979 (CMS, or the Bonn Convention)**<sup>3</sup> requires Member States to strictly protect these animals, conserve or restore the places where they live, mitigate obstacles to migration and control other factors that might endanger them. It was instigated in recognition of the fact that migratory animals can only be properly protected if conservation activities are carried out over the entire migratory range of the species. All European bat species are listed in Appendix II of the Bonn Convention. The Eurobats Agreement was set up under this Convention in 1994.

**1.2.3 The Convention on the Conservation of European Wildlife and Habitats 1979 (Bern Convention)**<sup>4</sup> requires Members to take appropriate and necessary legislative and administrative measures to ensure the special protection of the wild fauna species specified. All European bat species are listed in Appendix II (Strictly protected fauna species) with the exception of *Pipistrellus pipistrellus* which is listed in Appendix III (Protected fauna species).

#### **1.2.4 EU Action Plan**<sup>5</sup>

The Action Plan notes two main issues and targets. See the Action Plan for further details.

Issue No.	Issue	Target
10	Large mortality along roads that are built without consideration of local bat issues	A brochure on mitigation measures for road projects is published and a system to monitor road killing is developed in at least 14 Member States by end of

<sup>1</sup> [http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index\\_en.htm](http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm)

<sup>2</sup>

[http://ec.europa.eu/environment/nature/natura2000/management/docs/art6/natura\\_2000\\_assess\\_en.pdf](http://ec.europa.eu/environment/nature/natura2000/management/docs/art6/natura_2000_assess_en.pdf)

<sup>3</sup> Ref for CMS

<sup>4</sup> Ref for Bern Convention

<sup>5</sup> Ref for EU Action Plan

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		2021
11	Fragmentation through transportation infrastructures, disappearance of hedgerows or habitat degradation is affecting commuting roads and bat key habitats	Any initiative to reduce fragmentation of EU landscape is supported and a bat indicator is developed to measure fragmentation

DRAFT

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## 2 Literature Review (brief overview)

2.1 Summary and Key references – TO ADD

2.2 Results of Eurobats questionnaire – TO FOLLOW (JM)

2.3 Results of collation of bat species casualty data (Table) TO FOLLOW (JM)

**Comment [BK1]:** I think Primož is willing to update all of these as soon as the rest of the document will be close to finish.

DRAFT

### 3 How traffic infrastructure and operation affect bat populations

#### 3.1 Bat ecology

This section provides a general summary of bat ecology of particular relevance to the topic of the impacts of traffic infrastructure. More detailed information on the natural history of bats and species accounts of European bat species can be found in the EU Bats Action Plan (2018).

Bats are relatively long-lived animals for their size, with a lifespan often of over 10 years or even over 20 years (Altringham 2011), but they have low reproductive rates, usually each female gives birth to only one young per year (occasionally twins in a few species). Females from a colony gather together in maternity roosts before the birth and during the lactation period. Hibernating bats can congregate in large numbers in favoured sites. Bats cannot quickly replace any losses. Decreased breeding success or survival (through disturbance at roosts, sub-optimal conditions in roosts or habitat) may take some years to become apparent. Bats are thus vulnerable to disturbance, particularly at critical times, to damage and loss of roosting sites and to intentional or incidental killing. Hence bat species have protected status in many countries.

There is great variability between species. Some undertake long-distance seasonal migrations across parts of their range. For example noctule species *Nyctalus* spp and Nathusius' pipistrelle *P. nathusii* travel 1,000km between winter and summer habitats and roosts Eurobats [reference]. Myotis species have been recorded to travel 60 km to swarming sites in the UK [reference]. Species that are considered to be relatively sedentary still travel many kilometres between roost sites and foraging areas, distances which may be increased during dispersal [Rf example?].

During the summer breeding season, bats typically have large home ranges compared to other small mammals. Some species have specialised prey and preferences and consequently use particular habitat types predominantly for foraging [add examples], whilst others exhibit more generalist traits. Whatever their preference, all bat species utilise a variety of habitats and habitat features through their requirement to cross large areas of the landscape to reach favoured foraging sites or roosts and are therefore affected by a wider range of environmental disturbances than many other small mammals (Altringham 2011).

##### 3.1.1 European bat species

The Eurobats publication [title] lists xx species of xx families recorded as resident or migratory in the Eurobats area. One species of fruit bat is found within the Eurobats area (*R. aegyptiacus*). All other bat species are dependent on insect prey caught in flight, or gleaned from vegetation or other surfaces. Two bat species have been shown also to take larger prey: *Myotis capaccini* has been shown to be able to catch small fish [reference] and *Nyctalus lasiopterus* [reference] preys on small migrating song-birds [reference].

Insectivorous bats use sonar to emit high-pitched echolocation calls that bounce off objects in the vicinity. Bats use the returning information bouncing back to their ears to tell their own position, the position of landscape features and the position and the size and position of their insect prey. Bat echolocation calls are mostly above the range of human hearing, though some bats also produce lower frequency echolocation calls and social calls that may be audible to humans.

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Most research on the impact of traffic infrastructure on bats has focused on insectivorous bat species in developed countries (in particular western Europe and north America). The list of bat species recorded as road traffic casualties comprises (Table ?) almost all bat species recorded in the Eurobats area. Thus all bat species are considered to be susceptible to impacts, however some are more vulnerable than others.

MORE TO ADD [Any specific information on the impact on fruit bats. Check S. African Australian research?] Add IENE refs

### 3.1.2 Bat guilds

In generalizing about risks posed to different bat species and in mitigating impacts, there is value in categorizing bats into *guilds*, according to their foraging strategy, echolocation behaviour and morphology (Abbott 2012, Frey-Ehrenbold et al. 2013)).

Peak call frequency and bandwidth are good predictors of bat vertical distribution (Roemer 2018). Bat species that are clutter-adapted (see Table ?) are low-flying and highly manoeuvrable. They spend more time in close proximity to the ground and are therefore more susceptible to road traffic mortality due to collision. The open-adapted species, *Nyctalus* and *Tadarida* species fly at higher altitude and may be more susceptible to mortality due to collision with aircraft at height, although evidence of impacts is limited (see Chapter 7) [reference - See Voigt et al, 2018 BioScience and 2019]

The behaviours for each guild may be used to some extent as a proxy for species and in habitat types where published evidence is lacking. However, the extent to which understanding / information is transferable between species is variable, depending on whether the species are generalists or have specific requirements. This needs to be taken into account in the risk analysis for traffic infrastructure (see Chapter 7.)

NB. The risks of this approach need to be recognized and acknowledged. Research and monitoring should be undertaken to support and verify the assumptions wherever possible.

[Illustration of guilds and habitats to add - ask T McOwat, or Medinas?]

<b>Guild*</b>	<b>Flight and foraging characteristics</b>	<b>Species / species groups</b>
Short range echolocators (SRE)  Narrow space foragers  Clutter adapted	Low and slow flight. Hovering. Glean from vegetation and on the ground. Forage by flutter detecting, passive or gleaning	<i>Rhinolophus sp</i> <i>Myotis sp</i> <i>Plecotus sp</i> <i>Barbastellus sp</i>
Mid-range echolocators (MRE)  Edge space aerial foragers	(open habitats with background clutter) Aerial hawking, canopy-gleaning and hawking. Trawling.	<i>Pipistrellus sp</i> <i>Hypsugo savi</i> <i>M. daubentonii</i> , <i>M. dasycneme</i> , <i>M. cappaccinii</i>
Long range echolocators (LRE)	Fast flight. Open-aerial hawking	<i>Eptesicus sp.</i> <i>Vespertilio</i> <i>Nyctalus sp</i>

Open-space aerial foragers		<i>Tadarida</i>
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Figure X Guilds of bat species groups (after ?, Frey-Ehrenbold et al., 2013) and their typical flight and foraging characteristics. NB. Bats can alter their echolocation calls to some extent depending on the particular environment or situation.

### 3.2 Impacts on bat abundance and species diversity

Roads have been shown to adversely affect both bat activity and species diversity across the globe (e.g. in the USA Kitzes & Merenlender, 2014, van der Ree, 2015). Bat roosts, foraging habitat and commuting routes can be destroyed and bats disturbed during the construction phase; habitat quality can be reduced through the effects of fragmentation or changes in management practices; bats may be reluctant to travel across the new infrastructure to access roost or foraging resources even when those resources remain unaltered; and finally, bats may be killed as a result of collision with vehicles.

Impacts may be short term and reduced through effective mitigation, or may persist or increase in the long term, exacerbated by cumulative effects and the inability of bat populations to recover quickly. Wildlife populations have long response times to increases in fragmentation (see Figure X *The major ecological impacts of roads on animal populations?*). This is particularly true for bats, which are relatively long lived, but have a low reproductive rate and may not breed until their second year.

The topic of traffic infrastructure and bats has only relatively recently been the subject of academic study. New techniques e.g. infra-red, [reference – Roemer] and genetic studies [reference – Dietz] increase our understanding of bat behaviour and impacts of traffic infrastructures and operation on bat populations.

#### Two broad categories of impact

This document separates the impacts into two main types - firstly **impacts on habitats used by bats** and secondly **direct mortality through collision**.

Impacts on habitat affect the ability of the area/habitat to support an aggregation (colony or population) of a particular species of bats and to facilitate movement between aggregations. Road and other linear infrastructure habitats may be used for local commuting behaviour between roosts and foraging sites; dispersal between separated populations; long distance migrations; and dispersal / range expansion (Bennet, 1991).

Direct mortality of individual animals through collision with vehicles may have limited impact if few individuals are affected but can be significant if extrapolated over a large area, or losses are high at a specific location.

It is recognised that in practice, these factors overlap and interact in a complex way. Any consideration of the impacts of a traffic infrastructure scheme should consider both types of impact for each species affected. Overall the aim should be for infrastructures to be permeable, allowing continued movement between habitats and maintaining sufficient good quality habitat to sustain bat populations. Where direct mortality may potentially be high at specific locations, targeted mitigation is needed that will be effective in minimising losses whilst maintaining permeability.

#### 3.2.1 Road-effect zone

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The “**road-effect zone**” is the area of land (both the road itself and the adjacent landscape) that is affected by the traffic and associated infrastructure (Forman and Deblinger, 2000). The effects include habitat modification, disturbance, pollution (noise, light and chemical) and generally have a negative impact on wildlife (Van de Ree et al, 2015). The size and shape of the zone is determined by features of the road, traffic, the landscape, climate, the sensitivity of the species and the ecological processes affected.

In one study in the UK a decline in activity of the common pipistrelle *P. pipistrellus* was observed up to at least 1.6km from the road (Berthinussen & Altringham, 2012). A major road in France was found to have found that major roads had a negative impact on the activity of 5 taxa ? bats at distances up to 5 km.

A study in Portugal showed that even low and medium traffic roads have major negative impacts on bats. Bat activity and diversity increase with distance from roads. Effects varied seasonally and by species: impacts were less noticeable in the mating and swarming periods; activity of SRE and MRE species was found to be negatively affected by proximity to roads. In contrast, road verges are important foraging areas for long range echolocators and *P. kuhlii* (Medinas et al, 2016).

### 3.2.2 Genetic effects

Genetic isolation as a consequence of habitat fragmentation has been reported in populations of *R. hipposideros* (Dool et al. 2016, Claireau, 2018).

MORE TO ADD

### 3.2.3 Changes in habitat availability and quality

Construction of traffic infrastructure may destroy or damage bat roost sites, flight paths and feeding areas. This is especially the case when extensive changes in landscape and habitats are planned. High activity of foraging and commuting bats along operational roads that sometimes occurs in different habitats, landscapes and regions [Reference] indicate that changes of habitats due to traffic infrastructure construction do not necessarily adversely affect their foraging and/or commuting functionality for the bats generally, though some species may always be affected [Reference]. The presence of habitat favourable for bats – notably woodland – is linked with significantly reduced barrier effects but a heightened risk of collision (Fensome & Mathews, 2016).

At least 80 km<sup>2</sup> of the landscape is affected for every 25 km of road; the scale of this impact indicates a barrier effect (Berthinussen & Altringham 2011, Berthinussen 2013).

The impacts are species-specific and related to habitat. The presence of habitat favourable for bats – notably woodland – is linked with significantly reduced barrier effects but a heightened risk of collision (Fensome & Mathews, 2016).

Loss of roost sites, especially in the areas where those are scarce, would generally have impact that is more significant. However, even small decrease in foraging potential may have long-term effects such as decrease of biological fitness of individuals, which may also affect populations, especially migratory species. Construction of traffic infrastructure may also increase foraging potential of the habitat for bats, e.g. increase in clearings and inner edges within forests and

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attraction of aerial insects in otherwise less structured landscapes, which could lead to an increase in bat activity and, thus, risk of fatalities.

### 3.2.2.1 Habitat and roost destruction

The replacement of habitat by hard surfacing removes significant areas of habitat, e.g. 7 ha for every 10 km of 7 m wide, two-lane, single carriageway road. Further habitat is lost to roadside hard shoulders, verges, junctions, service areas and other structures (Berthinussen & Altringham, 2015). Loss of habitat means loss of commuting routes, foraging habitat, breeding, resting and hibernation sites.

Roosts are often legally protected from destruction and the provision of replacement roosts is required as part of the mitigation and compensation process. However the extent of roost loss due to developments is difficult to quantify as bats move roosts frequently and do not always leave evidence of use.

MORE TO ADD - See EU Action Plan p41

### 3.2.2.2 Barrier effect and habitat fragmentation

Severance of flight/commuting routes by roads is a key concern for the conservation of bat populations (Bach et al 2004, Schorcht et al 2008; and Kerth and Melber 2009, O'Connor et al. 2011). Some species will make large detours to avoid gaps in otherwise continuous corridors (Limpens & Kapteyn 1991). Severance may disrupt feeding activity and place an energetic burden on commuting bats (Hinde 2008).

Roads are a potential barrier to daily movement between foraging areas and roosting sites, and to seasonal movements especially for bat species that are reliant on connectivity of habitat features [Kerth & Melber 2009, Melber et al. 2012 Reference Frey-Ehrenbold, Bontadina,]

Barrier effect and collision risk are inversely correlated.

The effects of railway lines are less well studied, but Lüttman (2012a) noted that *Myotis* species avoided the area 10 – 25m from high speed railway line located in woodland even when trains were not passing through. Vandeveld *et al.* (2014) found that railway verges did not significantly influence foraging/commuting activity of common bats, but had a negative effect on specialist *Myotis* species. In an intensive agricultural landscape with limited semi-natural elements, railway verges were a significant habitat for MRE and LRE species (*P. pipistrellus* and *N. leislerii*).

### Habitat fragmentation

### 3.2.2.3 Habitat fragmentation

TO DO

### 3.2.2.34 Pollution - light, noise, chemical pollution

Disturbance from vehicles (noise, lights) can discourage bats from flying across roads (Bennet and Zurcher, 2013) and reduces foraging efficiency for some species (Siemers & Schaub, 2011) and may significantly increase barrier effect.

#### Light pollution

Road lighting deters some species from approaching roads (particularly SRE species), but insects congregating around street lights can be an attractant to light opportunistic MRE and LRE species (Rydell, 1992?), but puts them in danger through proximity to traffic.

**Comment [BK2]:** Perhaps this can be included in 3.2.2.2. as a additional paragraph, since barrier effect is the main cause of fragmentation

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ADD TEXT FROM Eurobats publication series No 8 (Voigt et al (2018), Guidelines for consideration of bats in lighting projects.

Noise pollution – TO ADD

Chemical pollution – TO ADD (See EU AP p53)

### 3.2.2.45 Positive impacts

TO ADD

### 3.2.4 Collision

Introduction TO ADD

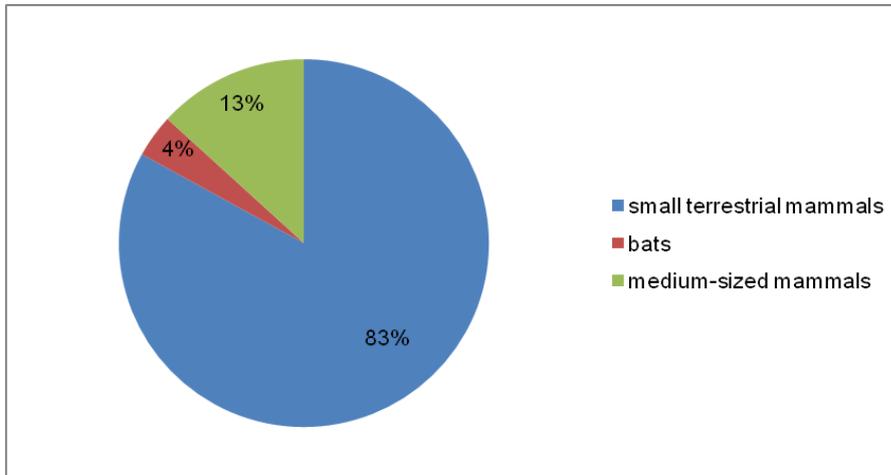
#### 3.2.4.1 Risk and impact

Insectivorous bat species are highly manoeuvrable but particularly vulnerable to collision when crossing open ground and roads (Richarz, 2000, Bickmore, 2003). Most fly at a height of less than 4m above the ground putting them in the same zone as road and rail traffic (Berthinussen & Altringham, 2012b). They fly at low speeds (<20 km/h) and weigh between 4 – 30g so are vulnerable to being drawn into the slipstream of passing vehicles. Many species use linear landscape features, such as woodland edges and hedgerows as navigational aids (e.g. Limpens and Kapteyn 1991). Bats using such features are put at risk of collision when hedgerows etc. are located alongside road and railway lines, or are bisected by them. SRE bat species (see 3.1.2) are particularly vulnerable as they are more reliant on vegetated habitat features as flight routes and also more likely to fly at low level when crossing open ground [reference]. The risk of collision depends on the local density of the species, which will depend on its abundance in the area and the presence of suitable habitat, the amount of time spent in the collision risk zone and the simultaneous presence of both bats and vehicles in the same location (Jaeger et al., 2005; Zimmermann Teixeira et al., 2017).

However as Table X shows, all European bat species have been recorded as casualties of traffic infrastructure. Road collision risks in a species depend on (1) its local density, (2) the proportion of time spent in the zone at collision risk and (3) the simultaneous presence of bats and vehicles in the zone at collision risk It is therefore necessary to take each of these variables into account when investigating road collisions. Indeed, when comparing two different road locations within different landscape features, a higher bat acoustic activity (used as a proxy of bat density) does not necessarily lead to a higher proportion of flights at collision risk for all species (see Abbott et al., 2012). A measure of per capita mortality risk is essential to avoid wrong recommendations for the siting of mitigation measures (Zimmermann Teixeira et al., 2017).

Unlike larger mammal species that are commonly killed on roads, such as deer and badgers, bat road casualties are unlikely to be found without targeted survey work. Bat carers occasionally receive injured or dead bats that have been hit by cars and there is anecdotal evidence of collisions noticed by drivers. Most evidence is gained as a result of systematic survey or road edges (e.g. Lesinski, 2007, Billington (date) & others. However this is still problematic as the small corpses may be thrown some distance from the road, remain stuck to the vehicle, or be removed by scavengers. [Reference].

**Comment [BK3]:** In quite systematic surveys of all mammal traffic casualties we did along minor road in prime bat habitat, bats seem to be far less represented compared to similar-sized terrestrial mammals, which may be an important point (I've added the graph from the publication translated into English). However, the point from the last sentence still stands - we don't know the removal rates. Furthermore, even small additional mortality may be threatening to bat populations (unlike to small terrestrial mammals).



MORE TO ADD

### 3.2.4.2 Effects of habitat on risk

TO ADD – see Roemer

### 3.2.5 Cumulative effects

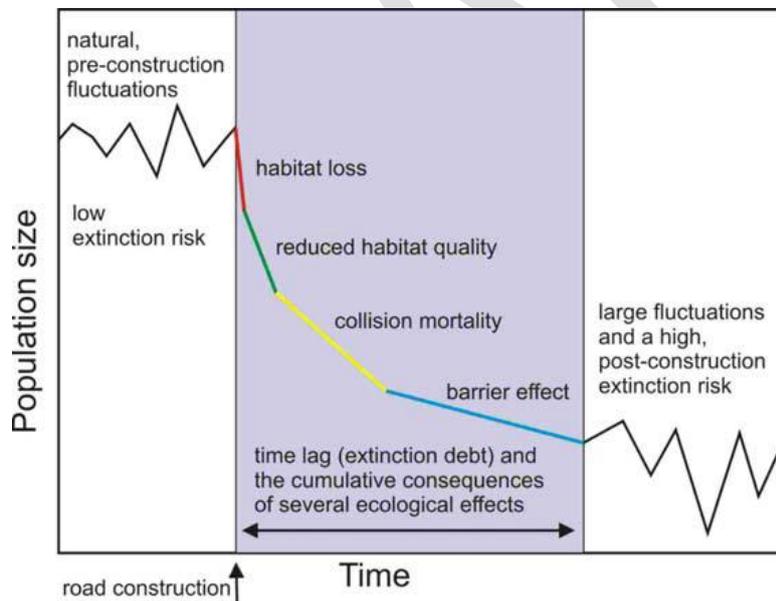


Figure X The major ecological impacts of roads on animal populations illustrated together with the time lag for their cumulative effect (Altringham & Berthinussen, – after Forman et al, 2003) [NOTE – have permission from Defra to use this]

MORE TO ADD

DRAFT

## 4 Planning and Impact Assessment of Road Construction and Upgrade of Existing Roads

The approach in the planning procedure and impact assessment of roads construction and upgrade will in general be no different than in other building project. The main difference is the scale, and that brings challenges to the planner and ecologist. Projects tend to cover many kilometres of road, potentially crossing many commuting routes and foraging areas and passing many roosting sites, maternity sites and hibernacula that may be affected by the changes caused by the building process or the resulting (changes in) roads.

Small scale road upgrading schemes, such as road widening may have less impact because of their smaller scale, but important bat habitats may still be lost, e.g. buildings and roadside trees used as roosts and hedges used as flight routes.

### 4.1 Early planning phase

Taking bats into account early in the project, during the planning phase usually pays off later in the project. It will save to form a first overview of the scale of mitigation or compensation measures in the early planning phase than before or during construction or upgrading.

Using known relations of bats with the landscape and existing knowledge of the occurrence of bats in the area, from distribution atlases, NGO's, or local experts or volunteers is a first step. Are there species present that are very sensitive to changes in the landscape? Are there roosts or hibernacula known in the planning area? With such knowledge, the survey for the EIA can be planned more efficiently. Usually, for taking roosts into account, the area for which this desktop survey is done for an area of 1 km surrounding the road, but this may need to be expanded for sensitive species or species with a large flying range.

In the case of new road construction, there will a route corridor selection phase. This is the planning phase when multiple variants of the route are being considered. If very rare, sensitive species occur, or species with a high conservation status, or species for which effects of roads cannot be mitigated, are present in the planning area, adapting the route may avoid time loss or financial costs necessary to mitigate or compensate its effects.

Most road planning is under government ministries or departments where information, although public, is usually contained in internal reports ('grey literature') that are not broadly distributed. Some of this work has been reported in conference proceedings available on the internet [e.g. International Conference on Ecology and Transportation (ICOET), formerly ICOWET ('W' for Wildlife)], but most has not been published in the primary literature.

Therefore, in an era when most scientific results are widely available through the publication process, road mitigation research falls somewhat behind. There are two main reasons why most research evaluating mitigation success has not been reported in the scientific literature. First, the research is mostly conducted in a specific applied setting in which information is desired for a particular wildlife crossing project. The government agencies conducting the work often do necessarily have an incentive or requirement to publish the work more broadly. Secondly, the scarcity of adequate and well-planned pre-construction survey and comparative post-

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construction monitoring methodologies and reporting impedes the evidence-based evaluation of the effectiveness of current avoidance, mitigation and compensation measures (Bickmore 2003, Forman et al. 2003, Hinde 2008, Altringham 2008, O’Connor et al. 2011, Berthinussen & Altringham 2012, 2015, Elmeros & Dekker 2016, Elmeros et al. 2016b), while some of these measures have even been proven to be ineffective (Berthinussen & Altringham 2012, 2015, Stone et al. 2013).

## 4. 2 Environmental impact assessment (EIA)

It is necessary to conduct detailed baseline bat surveys as part of impact assessments where works are proposed in order to have a good understanding of all bat populations and their conservation status. This information is essential for assessing the possible impacts of the proposed works on bat populations affected and for developing a mitigation strategy to minimise negative impacts and look for enhancement opportunities.

Monitoring of bat populations, and of individual mitigation features of the scheme is required during and after construction to assess the impact of the works and the effectiveness, or otherwise, of the mitigation measures (see 6 Monitoring). It is good practice to consider monitoring when designing the survey methodology to facilitate consistency. Although this can take place at a later stage of the process, it is better to design the two together and use later opportunities to review and revise the process as necessary.

### 4.2.1 Pre-survey assessment = Preliminary ecological appraisal

The objective of the Environmental Impact Assessment (EIA) is to identify and quantify any significant impacts on bat populations likely to arise from the construction and use of the road. To do this, first a pre-survey assessment is done, using the occurrence data from the desk study from the planning phase combined with a landscape analysis. Using knowledge of the ecology of bats, it is estimated in where bat roosts, flight routes and feeding areas are predicted to occur. The first assessment forms a preliminary assessment of the impact of the project on bats and the likely necessary mitigation. Taking into account information on where bats are known to be present, the survey strategy can be developed and an indication gained of where additional survey effort is needed. It may become clear that the whole scheme area must be surveyed.

It will be necessary to repeat pre-construction surveys to provide up to date information if there is a delay of 2 – 3 years, or more between the surveys and the start of construction. The length of delay triggering updated survey information should be based on national guidelines or legislation. It should also be specified in the pre-survey assessment report for the particular scheme to allow for local circumstances.

### 4.2.2 Survey

During the survey, roosts, flight routes and important feeding areas are assessed [refer to the Eurobats’ documentation on feeding areas].

It must be taken into account in the planning process that, a survey will take at least one year as bats changes their behaviour seasonally throughout the year. The presence of roosts and flight routes can be established In spring, summer and autumn. In winter, the importance of hibernacula can be determined.

**Comment [BK4]:** As far as I know the principles are more or less the same wherever standard EIA and/or EclA is obligatory, which is vast majority of the range states (though I have no knowledge about situation in Russia for instance)

**Comment [JD5]:** I realise this is more or less the Dutch approach: first a quickscan, followed by a tailored field survey (if necessary). Not sure how well this translate to the whole of the Eurobats member state area. Or if this approach is even preferable!

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The most challenging aspect of the survey is to identify flight routes. Here, the exact location of the route is important, not only for the assessment, but also for later in the process, if mitigation turns out to be necessary. As can be read in **6 Mitigation**, it is essential that mitigation to help bats to cross the new road safely is placed along the bats’ existing flight route. Bats may change their routes as a result of habitat changes, e.g. removal of hedgerows. Ideally, habitat continuity will be maintained prior to, and during, construction to encourage bats to continue to use the same flight routes and roosts, otherwise it will be necessary to update survey information and amend mitigation proposals.

Using standard bat detector surveys alone may not be sufficient and flight path tracking (Roemer and Claireau, 2018) or night vision equipment may be needed to pinpoint the exact crossing points (see Case Study) TO ADD.

FURTHER DETAILS OF SURVEY METHODOLOGY TO ADD & REFERENCE TO EXISTING SURVEY GUIDANCE

#### **4.3 Evaluation**

In this phase, the data gathered is combined with the knowledge of impacts that roads have on each of the species and their ecological functionality in the scheme area. If the road will have a significant impact on these that cannot be avoided, then mitigation or compensation must be planned [see **Chapter 5** and **6.4 Reporting**].

## 5. Avoidance, Mitigation and Compensation

Roads and other traffic infrastructures may have significant impacts on bats (see Chapter 3). Since bats are protected by international and national legislation in all European countries, impact assessment should determine which are the expected impacts of the particular traffic infrastructure development (including reconstruction and maintenance) on bats and their habitats prior, during and after construction and what is their significance. If significant adverse impacts are expected, impact assessment should also provide effective and adequate measures to avoid and then to mitigate (if avoidance is not possible) these impacts and, finally, to compensate for any residual effects that cannot be completely avoided or mitigated. This will also be necessary if any unpredicted significant adverse impacts are determined by post-construction monitoring. Effectiveness of implemented avoidance, mitigation and compensation measures should also be monitored, against baseline data collected during impact assessment prior to construction, and changes suggested if needed, until success has been proven.

In general, the most significant potential adverse impacts of any traffic infrastructure on bat populations are loss of habitats and their key elements (roosts, foraging area and commuting paths), disturbance (by traffic itself and operation of supporting infrastructures, but also by construction, reconstruction and maintenance and collision mortality). The significance of impacts will depend on the species ecology and features of the particular site and project features (see Chapter 3). Thus, effective and adequate measures for avoidance, mitigation and compensation of any traffic infrastructure can only be designed based on the specific features of presence and activity of bat species and populations at the site (and in vicinity) as determined by impact assessment and on the features of the particular development (Bickmore 2003, Limpens et al. 2005a, National Roads Authority 2005, Hinde 2008, O'Connor et al. 2011, Berthinussen & Altringham 2015, Elmeros et al. 2016a). Therefore, these measures will always have to be site-specific and most often also species-specific (Limpens et al. 2005a, National Roads Authority 2005, Hinde 2008, O'Connor et al. 2011, Berthinussen & Altringham 2011, 2012, 2015, Elmeros & Dekker 2016, Dahl Møller et al. 2016, Elmeros et al. 2016a).

Collision risk and barrier effect for most species are likely to be inversely proportional, i.e. a smaller barrier effect equals a higher collision risk and vice versa. Therefore these two adverse impacts should always be considered together. Measures developed and implemented should transfer bats safely across the road, preventing or minimizing barrier effect and collision risk simultaneously; otherwise, increased permeability might be outweighed by risk of collision mortality (Limpens et al. 2005b, Wray et al. 2006, Altringham 2008, O'Connor et al. 2011, Berthinussen & Altringham 2011, 2012, 2015 Dahl Møller et al. 2016, Elmeros et al. 2016a). This can be a particular challenge as factors other than bats need to be considered when planning an infrastructure project. The ability, or otherwise to mitigate for direct mortality should be considered early on in the project as changes to the design of the scheme that increase permeability may remove high risks, rather than requiring them to be mitigated. [e.g. A487 Porthmadog if permission given to include this].

A high level of understanding of the ecology of the different bat species affected by a scheme is essential for developing adequate and effective measures, therefore advisors to the project need to have expert knowledge of the species and the type and scale of the development (Bickmore 2003, National Roads Authority 2005, Limpens et al. 2005a, Elmeros et al. 2016a).

## 5.1 Avoidance

The best strategy to prevent adverse impacts of any traffic infrastructure on bats and their habitats, both in terms of bat protection and economic cost, is avoidance of impacts by preventive planning. This is where bats are taken into consideration during the planning phase of the traffic infrastructure development project (including reconstruction and maintenance), even already at a strategic/regional planning level, to avoid the necessity of complex mitigation schemes that are not only expensive but also of questionable effectiveness.

### 5.1.1 Preventive planning of traffic routes

In general, the highest **mortality** is expected in areas where bat activity is focused – commuting routes, important foraging areas, close to roosts, particularly for species and populations that are at higher risk due to their specific behaviour and ecology (see [Chapter 3](#)). Furthermore, **disruption and destruction of these key habitat elements** would also have significant adverse impact, particularly for species that are more susceptible to barrier effect due to their specific ecology (see [Chapter 3](#)).

Therefore, routes of roads and railways as well as locations of supporting infrastructures should be selected to avoid important bat habitats and their key elements as much as possible (Bickmore 2003, Limpens *et al.* 2005a, b, National Roads Authority 2005, Hinde 2008, Nowicki *et al.* 2009, Elmeros *et al.* 2016a). Especially disruption of commuting routes and destruction of roost sites have to be avoided, or at least kept at the minimum, because otherwise very complex and expensive mitigation schemes will be necessary. However, no such cases in which proposed roads have been rerouted to avoid key bat habitat are known (Altringham & Kerth 2016).

The most important bat habitats and their elements should be identified and avoided already at a strategic/regional planning level. Since knowledge of bat species ecology and their distribution for most of the areas is insufficient, bats distribution and habitat use will mostly have to be estimated at this stage of planning. Expert judgement based on understanding of ecology of bat species and on landscape and habitat features may be used (Bickmore 2003, Limpens *et al.* 2005b, National Roads Authority 2005). However, habitat suitability modelling is preferred since it has been proven as a reliable and an efficient tool to predict bats distribution and habitat use on different spatial scales and being able to quantify probability and reliability (Jaberg & Guisan 2001, Razgour *et al.* 2011, Becker & Encarnação 2012, Steck *et al.* 2012, Bellamy *et al.* 2013, Altringham & Kerth 2016). Both, expert judgment and habitat suitability modelling, can be based on already available data sets, but usually some targeted survey will be needed (Bickmore 2003, Limpens *et al.* 2005b, National Roads Authority 2005, Razgour *et al.* 2011, Becker & Encarnação 2012, Steck *et al.* 2012, Bellamy *et al.* 2013). Models taking into account multiple variables (e.g. habitat availability, bat roost sites, relevant project characteristics) may aid assessment of impacts (Bennett *et al.* 2013).

During the later phases of planning and development (including reconstruction and maintenance), habitat suitability modelling outputs can be used as a basis, but **not** as a substitute for impact assessment surveys (see [Chapter 4](#)). Only appropriate impact assessment can gather sufficient information on spatial and temporal patterns of bat activity and bat habitat use in the area of proposed traffic infrastructure (and supporting infrastructures) which will enable reliable and precise decision-making on final route selection and/or supporting infrastructures siting. All traffic and supporting infrastructures should be whenever possible planned out of the areas of important bat roosts, foraging area and commuting paths, as determined by impact assessment.

### 5.1.2 Preventive planning of the construction timetable

Bats may be **disturbed** by human activities, especially by major development, and they may be affected by disturbance on individual and, if repeated, even on population level (Natural England 2007). Appropriate impact assessment should determine if disturbance of bat roosting (while nursing and hibernating especially), foraging and commuting by construction, reconstruction and maintenance activities is expected. If significant impacts of disturbance are expected, measures to avoid (and to mitigate if complete avoidance is not possible) should be developed and applied, while compensation is not considered as possible.

Although roost destruction have to be avoided whenever possible (see 5.1.1), in certain cases some roosts will be destroyed or damaged (see 5.1.4). However, **fatalities caused by destruction, damage or disturbance of roost sites** while bats are present within them can be and have to be completely prevented. The risk of fatalities caused by destruction, damage or disturbance of roosts is highest for hibernating bats and for juveniles in maternity roosts (see Chapter 3).

The best strategy to avoid disturbance as well as fatalities in roosts is careful planning of the timetable (Limpens et al. 2005b, Keeley 2005, Green & Rasey 2006, Hinde 2008).

- Destruction, damage and disturbance of hibernation or nursery roosts, which may also lead to fatalities, have to be completely prevented in all cases by restricting any construction, reconstruction or maintenance activities in their vicinity while bats are present within them (i.e. works should be planned for the time of the year when bats are active but outside the maternity season).
- Destruction, damage and disturbance of any other roosts should be prevented whenever possible, also by restricting construction, reconstruction or maintenance activities in their vicinity while bats are present within them (i.e. if the roosts on the site are only used by bats seasonally, all works have to be planned for the time of the year when bats are not there).
- Disturbance of foraging and commuting should be prevented by restricting construction activities during times of the day and year when bats are active (i.e. works should generally be planned for the daytime; only during the winter they can be planned for after the sunset, but only if hibernation roosts are not present).

Annual and daily life cycles of bats vary across Europe and they also differ between species (see Chapter 3). Appropriate impact assessment will gather sufficient information on temporal patterns of bat activity and on bat roosts on the site and, thus, on case-by-case basis, determine the appropriate periods for construction, reconstruction or maintenance works that may affect bats. However, since many bat species change their roosts frequently, additional **surveys of roosts immediately prior** to any tree felling or destruction of other structures identified during impact assessment as having potential to support roosting bats is needed and timetable changes applied if necessary (Keeley 2005, Limpens et al. 2005b, Nowicki *et al.* 2009).

### 5.1.3. Prevention of accidental roost destruction

During construction, reconstruction or maintenance works, manoeuvres of worksite machinery and other activities may accidentally destroy or damage trees and other structures having potential to support roosting bats (Hinde 2008, Nowicki *et al.* 2009). To avoid accidental destruction, roosts on the site and in immediate vicinity identified

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during impact assessment should be marked (flags, tags, etc.) and/or fenced during the works (Keeley 2005, Nowicki *et al.* 2009).

#### 5.1.4. Prevention of fatalities in roosts

Intentional destruction of bat roosts, especially while bats are in them, is generally prohibited by law and must be avoided (see **Chapter 3**). Appropriate impact assessment will identify bat roosts on the site and the temporal patterns of bat presence within roosts. However, destruction of some identified or potential bat roosts may be inevitable in certain cases (e.g. during roads/railways construction/reconstruction in forests, reconstruction/maintenance of bridges).

Exceptionally the destruction of identified roosts may be allowed (i.e. exemption) but normally only if it is not a maternity or a hibernation roost and if destruction is absolutely unavoidable. Destruction may only be carried out when bats are absent, which must be confirmed by survey immediately prior to destruction (Keeley 2005, Limpens *et al.* 2005b, Nowicki *et al.* 2009). Only very exceptionally can an occupied roost be destroyed and only after the safe removal of bats by exclusion as a last resort to avoid fatalities (Keeley 2005, Limpens *et al.* 2005b, Hinde 2008, Nowicki *et al.* 2009). In most of the European countries exemption and exclusion procedures are legally regulated, they require extremely strong justification and they can only be done under special licence.

Exclusion of bats can only be done by a bat specialist. Licenced and planned destruction of an identified bat roost must be supervised by a bat specialist, in order to take any emergency measures that might be necessary to prevent unpredicted fatalities (Keeley 2005, Limpens *et al.* 2005b, Nowicki *et al.* 2009). The presence of bat specialist and/or suitably qualified and experience environmental officer is strongly recommended during any works in the vicinity of identified or potential bat roost that may cause destruction, damage or disturbance, as a precaution against unpredicted fatalities. Planning and licensing authorities should require this as part of the permitting process for actions that would otherwise be unlawful,

#### 5.1.5 Prevention of pollution – light, noise, chemical TO ADD

#### 5.1.6 Preventing collisions

Road collision risks in a species depend on (1) its local density, (2) the proportion of time spent in the zone at collision risk and (3) the simultaneous presence of bats and vehicles in the zone at collision risk It is therefore necessary to take each of these variables into account when investigating road collisions (see Abbott *et al.*, 2012).

In a study in France, Roemer demonstrated that tall and large trees along roads led to higher bat densities, and that dense vegetation (i.e. forests or forest edges) led to higher proportions of bats flying in the collision risk zone. She also showed that bats, contrary to expectations, flew most of the time parallel to the road axis, even in the presence of perpendicular tree rows [Reference].

#### 5.1.7 Consideration of cumulative impacts

### 5.2 Mitigation

A variety of strategies and structures have been used across the Europe to mitigate impacts of roads and traffic on bats, though only occasionally properly evaluated. Non-quantified data and even anecdotal record of bats using certain structures have quite often been used to demonstrate effectiveness of particular mitigation measures. However, use by individual bats, even in large numbers, does not guarantee the

**Comment [BK6]:** This is not the last version I wrote, so I inserted the latest text. Please note that, after a lot of thinking, I very strongly feel that the structure of this sub-chapter should be modified in certain parts (as elaborated below).

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survival of the population, i.e. usage does not equate effectiveness (Corlatti et al. 2009, Ree, Van der et al. 2007, Berthinussen 2013, Berthinussen & Altringham 2015, Dahl Møller *et al.* 2016). Berthinussen & Altringham (2015) suggested criterion, accepted also by Dahl Møller *et al.* (2016), that for a crossing structure to be effective at least 90% of crossing bats must use it to fly safely over or under the road. Although this is a precautionary figure and not all bats crossing at risk of collision will be killed, the potential increase of mortality rates within a population by 10%, or even by just 5%, would be unsustainable (Schorcht et al. 2008, Altringham 2008, see Chapter 3). Furthermore, only if such figures have been positively determined by a long-term monitoring using robust scientific methodology (see Chapter 6), effectiveness can be considered proven (Berthinussen 2013, Berthinussen & Altringham 2015, Dahl Møller *et al.* (2016)).

**Comment [BK7]:** I think that effectiveness have to be defined here, at least basically, so the text on particular measures would be comprehensible.

Only since recently proper and extensive studies and reviews of mitigation measures effectiveness have been available, the most comprehensive being those commissioned by UK Department for Environment Food & Rural Affairs – DEFRA (Berthinussen & Altringham 2015) and Conference of European Directors of Roads – CEDR (Elmeros & Dekker 2016, Elmeros *et al.* 2016a,b, Dahl Møller *et al.* 2016, Christensen *et al.* 2016, Dekker *et al.* 2016).

Based on these and other studies (e.g. Bickmore 2003, Brinkmann *et al.* 2003, 2008, Bach *et al.* 2004, Bach & Mueller-Stiess 2005, Limpens *et al.* 2005a, b, National Roads Authority 2005, Wray *et al.* 2006, Hinde 2008, Green & Rasey 2006, Altringham 2008, Bach & Bach 2010, O'Connor *et al.* 2011, Berthinussen & Altringham 2011, 2012, Abbott *et al.* 2012b, Lüttman 2012b, Berthinussen 2013, Berthinussen & Altringham 2015, Elmeros & Dekker 2016, Elmeros *et al.* 2016a, Dahl Møller *et al.* 2016, Christensen *et al.* 2016 etc.) a set of criteria to be met by any mitigation measure to be effective is identified, those are as follows:

- aimed for minimising barrier effect and collision risk (as well as possible genetic effects) simultaneously, i.e. to ensure permeability and safe crossing at the same time
- adequate for the affected species (with regard to flight ecology in particular)
- on a pre-existing traditional commuting routes
- functionally integrated into (connected to) landscape and habitats
- undisturbed and free of danger during the night (appropriate lighting, protective vegetation or screens, etc.)
- developed in advance and planned alongside development planning
- timely implemented (some have to be put in place before construction works some before operation)
- permanent and properly managed and maintained (included in management/maintenance plans).

An overview of structures and strategies used to mitigate impacts of roads and traffic on bats, along with recommendation or disapprove for their use, is given in next sub-sections (5.2.1.-5.2.3), while elaborated reviews can be found in DEFRA (Berthinussen & Altringham 2015) and, in particular, CEDR (Dahl Møller *et al.* 2016) report. Those measures proven effective are considered recommended, though none of them will have to be effective in all circumstances; crucial factors determining effectiveness are emphasised, though it should always be kept in mind that all the criteria set above have to be met. Measures whose effectiveness has not yet been proven by rigorous studies, though it's been indicated at least in certain circumstances and for certain species, are considered as potentially effective pending further research. Those proven ineffective in all circumstances are considered disapproved and should not be used or considered mitigation.

## 5.2.1 Maintaining habitat quality and connectivity

TO ADD

Structures and features to facilitate safe crossing (use vs effectiveness - see Monitoring section)

### 5.2.1 Effective = Recommended

#### 5.2.1.1. Fauna Overpasses

Fauna overpasses (often referred to as green bridges), are purpose-built bridges, usually over a major road or railway, aimed to mitigate the barrier effect of transport infrastructure for all terrestrial groups of animals; the distinction between the two types – wildlife overpasses and landscape bridges is artificial and is defined by a recommended width (Luell *et al.* eds. 2003). They are likely to be effective for all the bat species regardless of their flight ecology, while integration into surrounding landscape and habitats and resemblance to natural features are crucial factors determining their effectiveness for bats (Bach & Mueller-Stiess 2005, Bach & Bach 2010, Stephan *et al.* 2012, Berthinussen & Altringham 2015, Dahl Møller *et al.* 2016). However, due to demanding technical issues and large costs, it's not likely that fauna overpasses will often be used as a mitigation measure exclusively for bats, nonetheless, whenever fauna overpasses are planned, bats should be considered regarding their location and design.

#### 5.2.1.2. Bridges as Underpasses

Bridges and viaducts are structures built to lead traffic infrastructure across a watercourse or a valley; although usually not specifically built to mitigate the barrier effect for wildlife, they can still provide large and suitable underpasses (Luell *et al.* eds. 2003). Since built over the landforms that often define bat commuting and migration routes (and where foraging activity is also highly concentrated) they are likely to be effective for all bat species, providing that clearance height above water or vegetation is sufficient not to put the bats, species foraging in the open-air in particular, at risk of collision (Altringham 2008, Berthinussen & Altringham 2012, Abbott 2012, Abbott *et al.* 2012a, Dahl Møller *et al.* 2016). Bridges are also not likely to be built exclusively as a mitigation measure for bats, though whenever they are planned, bats should be considered regarding their location and design, clearance height in particular. Furthermore, embankments, which are often preferred alternative to bridges from economic point of view (Luell *et al.* eds. 2003), increase both barrier effect and collision risk for bats and other wildlife (Nowicki *et al.* 2009, Berthinussen & Altringham 2015, see Chapter 3); therefore, bridges are clearly preferable alternative in a long-term considering bat conservation and multiple ecological benefits (Luell *et al.* eds. 2003).

#### 5.2.1.3. Underpasses: Tunnels and Culverts

Tunnels and culverts are structures built under the traffic infrastructure, usually in hilly areas or where it is on an embankment, either as purpose-built wildlife underpasses or for other purposes – tunnels to lead minor roads, railways, tracks and lanes, and culverts (drainage pipes) to allow the passage of water (Luell *et al.* eds. 2003). Underpasses have been proven effective for all except open-air species, providing that their location and design does not require bats to alter flight height or direction, while species-specific effectiveness is determined by cross sectional area, height in particular, though not by length (Hinde 2008, Boonman 2011, Abbott 2012, Abbott *et al.* 2012b, Berthinussen & Altringham 2012, 2015, Dahl Møller *et al.* 2016). Recommendations have been set on required species-specific dimensions of the underpasses (e.g. Limpens *et al.* 2005b, Hinde 2008, Berthinussen & Altringham

**Comment [BK8]:** I give it a lot of thought and, because it's essential to mitigate barrier effect and collision risk simultaneously, I suggest not have sub-chapters related to particular effects, but as integrated mitigation measures, classified according to their effectiveness.

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2015), though further research is considered necessary (Dahl Møller *et al.* 2016); pending more information, general recommendation can be made (Berthinussen & Altringham 2015) that required heights are lower for woodland-adapted species (~3 m) compared to generalist edge-adapted species (~6 m), yet even narrow drainage pipes may be effective for certain species (Bach *et al.* 2004, Berthinussen & Altringham 2015). Furthermore, culverts seem to be more effective than tunnels, possibly because the watercourses function as commuting routes for many smaller low-flying bat species (Dahl Møller *et al.* 2016). Being cost-effective culverts can be used abundantly in areas where numerous commuting paths are intersected (if expected to be effective). Underpasses aimed for other purposes can also be adapted for bats (e.g. tunnels by restricted lighting, small wildlife underpasses and culverts made larger), especially if bats are considered during planning with regard to location and design.

#### 5.2.2. Possibly effective (in certain circumstances)

TO ADD

5.2.2.1. Hop-over (connecting canopies)

5.2.2.2. Modified bridges

5.2.2.3. Cutting/roadcut

5.2.2.4. Fences/screens

#### 5.2.3 Ineffective = Disapproved

TO ADD

5.2.3.1. Bat bridges, gantries

5.2.3.2. Signage gantries

5.2.3.3. Guidance/diversion

5.2.3.4. Traffic calming

5.2.3.5. Deterrents

Acoustic (Szewczak & Arnett 2007, Arnett *et al.* 2008) and electromagnetic (Nicholls & Racey 2009) deterrents have not yet been proven to effectively prevent bats from approaching wind farms let alone to reduce bat fatalities at operating wind farms. Also, the impact of such measures on other wildlife, like birds or insects, has not been assessed to date (Amorim *et al.* 2012). Therefore, although research of deterrents might have potential, those still cannot be considered to mitigate effectively bat fatalities.

MORE TO ADD

#### 5.3 Compensation

In contrast to impact on habitat, where loss of certain areas at the development site may be compensated by protection or restoration of appropriate areas of habitat outside of the site, the possibility of compensating for fatalities is questionable. Since the current levels of bat mortality caused by traffic and the impact on population levels is still not known, it is not possible to develop of well-based, adequate and measurable compensation schemes. is not possible. This is especially problem for long-distance migratory populations, because it would require improving their birth and survival rates hundreds of kilometres away from the development site, at a large scale and before the operation phase (Voigt *et al.* 2012). All of these are strong arguments in favour of avoiding or mitigating fatalities much as possible. However, since some fatalities may still occur even after all known all possibilities of avoidance and mitigation are exhausted, some compensation might be needed.

Some possible means of compensation known to contribute to preservation and improvement of bat populations and which may be a part of compensation schemes are:

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- Protection of habitats and their functional elements of the affected populations, above all roosts, foraging areas and flight paths.
- Improvement and/or restoration of appropriate habitats and their functional elements of the affected populations, above all roosts, foraging areas and flight paths.

These can be implemented outside but as close as possible to the development site, but also within the site provided that this would not further increase the risk of fatalities.

Compared to avoidance and mitigation, compensation is less efficient, in terms of bat protection as well as from the economic point of view – it is more costly and it is less certain that it will have the desired outcomes. Therefore, it should be used only as a last resort, when significant effects cannot be avoided or mitigated.

When it is necessary, compensation has to be well based (on appropriate IMPACT ASSESSMENT), species-specific, adequate, at least proportional to loss, timely, permanent and not destructive for other nature features. Possible means of compensation are protection, improvement and/or restoration of affected habitats and their functional elements, above all roosts, foraging areas and flight paths.

EXAMPLES TO ADD

#### 5.4 Recommendations

(in relation to mitigation (from Berthinussen & Altringham, 2015) OTHERS TO ADD – OR PUT IN SEPARATE SECTION AT THE END?

1. Mitigation should be considered during the planning and design stage of the infrastructure so that it can be incorporated effectively.
2. Crossing structures should be placed on the exact location of existing bat commuting routes. Attempts should not be made to divert bats from their existing commuting routes.
3. Crossing structures should not require bats to alter flight height or direction. This will depend on the topography of the site. If the road is to be elevated above ground level an underpass may be used to preserve the commuting route below it, or if the road is in a cutting a green bridge may be used to carry the commuting route over the road.
4. Crossing structures should maintain connectivity with existing bat commuting routes. Connectivity must be maintained with undisturbed bat flight paths (e.g. treelines, hedgerows, woodland rides and streams), and bat habitat (e.g. woodland) within the surrounding landscape. Crossing structures should not be exposed or sited within open ground.
5. Over-the-road structures such as green bridges should be planted with vegetation. Vegetation should be continuous and connected (see above) and sufficiently mature before road construction (e.g. by planting either relatively mature trees or fast growing tree species in advance of construction).
6. Underpasses should be of sufficient height. Underpasses should be as spacious as possible with height being the critical factor. The minimum requirements for underpass height will be species-specific. Required heights will generally be lower for woodland-adapted species (~3 m) compared to generalist edge-adapted species (~6 m), but larger underpasses will accommodate more species.

7. Green bridges should be of sufficient width. In addition to being vegetated, green bridges should be as wide as possible, to simulate ‘natural’ habitat as closely as possible. Further research is needed to determine exact dimensions, but a 30 m wide green bridge was found to be effective.

8. Crossing structures should be unlit. The effects of light on bats are species-specific but lighting should be avoided.

9. Access and connectivity must be maintained. It is important that access to crossing structures is maintained (e.g. grilles should not be installed on underpasses) and that connecting vegetation is retained indefinitely or for as long as the mitigation structure is required.

10. Disturbance should be minimised during installation of mitigation structures. For example, by limiting noise and light pollution along the bat flight path, minimising vegetation clearance, installing suitable temporary crossing structures (which should also be subject to monitoring and evaluation), completing the installation as quickly as possible and ideally avoiding the summer months when bats are most active.

**Comment [BK9]:** I already have, or I will include these recommendations in relevant sub-sections on particular measures above.

## 6 Monitoring

### Rail and air to add

#### 6.1 Introduction

In order to fully understand the impacts of a road on bat populations at a location, it is necessary to have baseline information on the status of bat populations in the area prior to the start of the scheme (see Chapters 3 and 4) and details of mitigation / avoidance / compensation undertaken to reduce impacts on bats (see Chapter 6). (For the purpose of this chapter, the term mitigation is used to include avoidance and compensation unless stated otherwise.)

- The purpose of monitoring at a road scheme may be two-fold – monitoring of compliance and of effectiveness.
- The pre-construction survey should complement the monitoring strategy by providing robust baseline data against which the impacts of the road can be assessed.
- It is essential to set specific monitoring objectives/questions early on, ideally when designing the pre-construction survey. These should be reflected in the monitoring strategy.
- Specific measurable criteria need to be set so that both compliance and effectiveness of mitigation can be determined.
- At each stage there should be a mechanism identified to address any problems preventing the mitigation from being effective. It is not sufficient just to monitor non-compliance, or mitigation failure.
- The level and frequency of monitoring should be appropriate to the scale of the project and its likely impact on bats.
- Monitoring reports should provide a clear summary of information including quantitative results, statistical analyses and conclusions. The reports should be publicly accessible and the raw data made available for analysis to further understanding of the impacts and promote effective mitigation. (Ref Resolution).  
**See Section on Reporting under Surveys.**

**Comment [JM10]:** JD comment - Do we need to stress why monitoring matters here, or was that included in the introductory chapter?

#### 6.2 Types of monitoring

**6.2.1 Compliance monitoring** is undertaken to check that works undertaken for mitigation / avoidance / compensation purposes have been carried out as intended; that any mitigation structures, hedgerows etc. have been constructed or planted in accordance with their design. Some “snags” are inevitable so there needs to be a system in place to identify where mitigation measures are not compliant with the design and to remedy them.

In the case of a planting scheme, if many young trees die off, perhaps due to unseasonal weather conditions, then there may not be a recognisable hedgerow for commuting bats to follow. The system of compliance monitoring should initially check that the planting has been undertaken using the tree species specified in the design and that the trees have been planted in the correct location. There should be regular checks to ensure that the planting has established. In the longer term, the vegetation should be habitat management plan for the scheme. It is not uncommon for mistakes to occur through a lack of understanding by the contractor of the need or rationale for specific items detailed in the design so that the constructed mitigation seems to be

**Comment [JM11]:** JD (Go into Deming cycle: plan-do-check-act?)

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compliant to the contractor, but fails to meet its objective. A common example is for fencing to be sited in the wrong location which will therefore not guide bats along the intended route, or for mitigation features to be discontinuous e.g. gaps between fencing and hedgerow which can encourage bats to fly through the gap, rather than along the linear feature.

For more complex mitigation structures such as the use of bat houses, there are numerous factors that can affect the likelihood of the mitigation being effective and which need to be considered when assessing the effectiveness of mitigation

**6.2.2 Monitoring of effectiveness** is undertaken to check if the measures taken have been successful in mitigating the negative impacts of roads. The distinction must be made between “effectiveness” and “use” (Ref Alt or Berth & date). For example, in the case of a newly planted hedgerow intended to guide bats to a safe tunnel under a new road; a number of bats may use the new flightpath however if the majority of bats continue to follow a traditional flightpath leading over the new road, which puts them at risk of collision, then the mitigation feature is “used”, but not “effective”. A monitoring scheme that simply observes bats’ use of the new mitigation feature will fail to pick up the critical information, i.e. that the mitigation structure is not functioning as intended. So, remedial action will not be triggered.

It is essential when designing a pre-construction survey and a monitoring strategy to set specific questions that both should answer. Ideally the survey should complement the monitoring strategy by providing robust baseline data against which the impacts of the road can be assessed. Specific measurable criteria need to be set so that the effectiveness of mitigation can be determined.

In many cases there has been a lack of good baseline data, making it difficult to draw reliable conclusions about the effectiveness of the mitigation at the site, or of the impacts of the scheme, or more widely of the effectiveness of particular mitigation techniques and strategies [References HA review, Altringham]. In some cases, this is because of the length of time that has elapsed since the initial assessment was undertaken and previous studies used survey techniques that are not comparable. Update surveys will be required where the survey information is considered to be insufficient to provide a baseline or where local circumstances have changed since the initial assessment. Changes of personnel also account for lack of continuity as different surveyors use different survey protocols.

Standardised survey methods, including the analysis and reporting of data have been put together in the UK in Bat Survey Guidelines, (Collins Ed,) though these do not specifically address large-scale infrastructure projects.

A research project was undertaken in the UK to develop a cost effective method for monitoring the effectiveness of mitigation for bats (Berthinussen and Altringham (2015) which provided standardised monitoring protocols. These are outlined below, but the original final report and provide detailed recommendations for monitoring, including data sheets/analysis ? Appendix ?

### 6.2.3 Monitoring large scale / population? Effects

[To ADD - short lead in text explaining why scale is important for the monitoring design]

#### 6.3.1 Landscape-scale effects

Large road schemes have a detrimental impact on species abundance and diversity (Berthinussen and Altringham 2012 a). It is likely that this results both from a reduction in the amount and quality of suitable habitat for foraging and commuting

**Comment [BK12]:** There are some elements in the Serbian guidelines for bats and EIA, though only as very rough guidance

**Comment [JM13]:** References from other countries?

JD We have a standard protocol (on intensity and time of year)

closer to the road and it is possible that disturbance from vehicles (noise, lights) that discourage bats from flying across roads (Bennet and Zurcher, 2013) and reduces foraging efficiency for some species (Siemers & Schaub, 2011).

Mitigation structures can be used to reduce severance impacts as well as reducing mortality impacts and these are discussed in the section on local scale impacts below. Reducing the impact of landscape scale effects is most likely to be successful if also considered at that scale, i.e. improving habitat away from the road can increase the carrying capacity of the area for bats. The aim of providing alternative high quality, well-connected habitat is more likely to be considered as compensation for impacts that cannot be effectively mitigated, such as the direct loss of foraging and commuting habitat through land-take, or reduction in quality through changes in the environment (increased disturbance, reduced connectivity). This sort of action requires a long-lead in time to identify the likely impacts of the new scheme, to consider areas of land that may be available and suitable for enhancement and to undertake the actions needed to improve the habitat. Availability of appropriate land may be a limitation.

Berthinussen and Altringham have suggested a methodology that can be used both for the initial assessment of the area pre-construction and for monitoring the landscape-scale impacts of the road once it is open. This type of survey and monitoring is appropriate for large schemes, such as new major roads and motorways. It is not necessarily appropriate for small schemes, although the information may be useful in general for assessing the accuracy of the predicted impacts of the scheme, or where there are other specific reasons such as assessing the impact of a scheme on a protected site, or at a particularly sensitive location, or to help assess the cumulative impact of development in an area. The detailed methodology is given in [REFERENCE].

### 6.3.2 Local effects

Monitoring of impacts should include all species at the site and consider the potential impacts of the scheme on each as identified from the pre-construction survey.

Monitoring effort should be proportional to the risk to the species and the importance of the species at the site. In this context, the assessment of risk should include an assessment of the likelihood of the mitigation being effective. There is a lack of evidence of the effectiveness of some mitigation techniques [REFERENCE] and more effort may be needed to demonstrate that novel or unproven techniques are effective. This will be beneficial to all parties in the long term.

In assessing local effects, monitoring effort should focus on areas identified as crossing places where mitigation has been undertaken. Evidence shows that mitigation away from existing crossing points is unlikely to be successful and that bats will continue to use traditional flight routes (B & A).

It may be advisable to monitor traditional flight routes if bats are not using mitigation crossings in case it is possible to make changes at those locations to influence bat behaviour, recognising that this is difficult to do successfully.

Mitigation needs to be monitored so that its effectiveness can be assessed and remedial measures taken if it is not. Success should be assessed by the number of bats crossing the road safely, e.g. a minimum of 90% of the number of bats previously using the crossing point.

- Monitoring during and after the construction phase is needed to ensure that the mitigation has been installed as intended, e.g. planting put in the right place before it is too late. Monitoring of success should also include flight routes that were identified but where no mitigation is planned. Ideally, control sites are included to provide a robust monitoring design.

**Comment [JD14]:** Text below removed – check if it appears in mitigation chapter.

Continuity of habitat features is important during the construction phase – e.g. use of fencing to maintain linear features along flightlines.

Lighting can deter some species but can encourage others so the effect of lighting needs to be considered carefully. In general light-spill should be avoided on areas where bats are flying. It may help to deter some species from accessing some areas which can be useful in very limited circumstances, but is not reliable or predictable enough to be used as generally as a mitigation.

**Comment [BK15]:** Although I would prefer to have a definition of effectiveness in the Mitigation chapter, I would still leave this part here, as clear recommendation of criterion to assess effectiveness.

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- Recommendations for monitoring are given in the report. The project used infra-red cameras but use of thermal-imaging cameras should also be considered. Casualty surveys may be considered in some circumstances but in general, observation of bat behaviour at mitigation features is considered more cost effective.
- Monitoring needs to be included in the package of funding post-construction (along with habitat management).

#### **6.4 Monitoring strategies and techniques (?)**

Most post-construction monitoring that has been undertaken to date has consisted of short term studies of specific mitigation measures. Infrastructure developments result in huge changes to the landscape, sometimes to the topography of an area as well as to the habitats. Monitoring bats' response to such change requires long term monitoring as vegetation matures and bats become accustomed to new roosting locations and different habitats.

MORE TO ADD

#### **6.5 Reporting on Monitoring**

Analysis of studies on impacts of roads has concluded that most reports are descriptive and lack robust study design [REFERENCES].

Interim reports can be used to prompt action on immediate problems that can be solved (e.g. where mitigation has been incorrectly installed).

MORE TO ADD

**BOX - Examples of mitigation and compensation features and monitoring methods – TO ADD**

## 7 Other Transport Infrastructure

### 7.1 Introduction

The vast majority of studies have looked at the impact of road infrastructure on bats and there are far fewer records of impacts associated with other types of traffic. Construction, or upgrade of railway and airport infrastructure occurs less often than road schemes. The scale of such projects should trigger a strict environmental impact assessment process. In practice, these have mostly focussed on mitigating the loss of habitats and roosting locations and little is known about the impacts of the operation of rail and airports on bats and the safety considerations and access restrictions associated with monitoring near railways and airports make it a challenging topic to study.

Racey & ? looked at the possible deterrent effects of radar associated with airports (and considered whether this may be useful in mitigating the impacts of wind turbines).

Flaquer et al, 2010 studied the effectiveness of wire fences installed between two tunnels on a high speed railway in Andalucia to help to divert bats from crossing the railway and towards and underpass.

MORE TO ADD

## 8 Conclusions and Recommendations

TO ADD

## 9. References and further reading

TO ADD

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## Glossary

TO ADD FROM NOTES

DRAFT

## List of bat species recorded as casualties of traffic (all types) in the EUROBATS region

Species	State	Transport type		
		road	rail	air
<i>Rhinolophus blasii</i>	MNE	+		
<i>Rhinolophus euryale</i>	FRA, GRC, ITA	+		
<i>Rhinolophus hipposideros</i>	BIH, CHE, DEU, ESP, FRA, GBR, ITA, HUN, MNE, POL, PRT, SRB, SVK, SVN, UKR	+		
<i>Rhinolophus mehelyi</i>	PRT, TUN	+		
<i>Rhinolophus ferrumequinum</i>	ARM, BGR, DEU, FRA, ITA, HUN, PRT	+		
<i>Myotis myotis</i>	DEU, FRA, POL, SVK, PRT*	+	+	
<i>Myotis oxygnathus (blythii)</i>	ARM, ESP, FRA, PRT*	+		
<i>Myotis bechsteinii</i>	DEU, FRA, GBR, PRT, SVK, TUR	+		+
<i>Myotis escaleri</i>	ESP, PRT	+		
<i>Myotis nattereri</i>	CZE, DEU, FRA, GBR, IRL, ITA, HUN, POL, PRT, UKR,	+		
<i>Myotis emarginatus</i>	CZE, ESP, FRA, GRC	+		
<i>Myotis mystacinus</i>	DEU, FRA, IRL, GBR, ITA, MNE, NOR, POL, PRT, SVN, UKR	+		
<i>Myotis alcathoe</i>	CZE	+		
<i>Myotis brandtii</i>	CZE, DEU, POL	+		
<i>Myotis daubentonii</i>	CZE, DEU, ESP, FRA, GBR, ITA, NOR, POL, PRT, SVN	+		
<i>Myotis dasycneme</i>	POL	+		
<i>Myotis capaccinii</i>	ESP, GRC, ITA, MNE,	+		
<i>Nyctalus lasiopterus</i>	DEU, FRA	+		
<i>Nyctalus leisleri</i>	CZE, DEU, FRA, GBR, ITA, POL, PRT, SVN	+		+
<i>Nyctalus noctula</i>	CZE, DEU, FRA, GBR, HUN, POL, SRB, SVK, UKR	+		+
<i>Pipistrellus pipistrellus</i>	ARM, CZE, DEU, ESP, FRA, GBR, HUN, ITA, IRL, POL, PRT, SVK, UKR	+	+	+
<i>Pipistrellus pygmaeus</i>	CZE, FRA, GBR, IRL, MNE, NOR, PRT, SVN	+		+
<i>Pipistrellus kuhlii</i>	DZA, ESP, FRA, GRC, IRQ, ITA, KWT, MNE, PRT, SMR, SVN, SYR, TUR, UKR	+		+
<i>Pipistrellus nathusii</i>	CZE, DEU, FRA, MNE, POL, SRB, UKR	+		+
<i>Hypsugo savii</i>	ESP, FRA, ITA, TUR	+		+
<i>Eptesicus nilssonii</i>	DEU, NOR, SVK	+		
<i>Eptesicus serotinus</i>	CZE, DEU, ESP, FRA, HRV, HUN, POL, PRT	+	+	
<i>Eptesicus serotinus / isabellinus</i>	PRT	+		
<i>Vespertilio murinus</i>	DEU, HUN	+		+
<i>Plecotus auritus</i>	DEU, FRA, GBR, IRL, ITA, NOR, POL, UKR	+		
<i>Plecotus austriacus</i>	DEU, ESP, FRA, ITA, POL, SVK	+		
<i>Plecotus macrobullaris</i>	BIH, ITA	+		
<i>Barbastella barbastellus</i>	CHE, DEU, ESP, FRA, GBR, POL, PRT, SVK, SVN, UKR	+		
<i>Miniopterus schreibersii</i>	ALB, ARM, DEU, ESP, FRA, POL, PRT	+		
<i>Tadarida teniotis</i>	ITA			+

\* PRT = species given as *M. myotis*/*M. blythii*

ALB = Albania, ARM = Armenia, BGR = Bulgaria, BIH = Bosnia and Herzegovina, CZE = Czech Republic, DEU = Germany, DZA = Algeria, ESP = Spain, FRA = France, GBR = United Kingdom, GRC = Greece, HUN = Hungary, HRV = Croatia, IRL = Ireland, IRQ = Iraq, ITA = Italy, KWT = Kuwait, MNE = Montenegro, NOR = Norway, POL = Poland, PRT = Portugal, SRB = Serbia, SVK = Slovakia, SMR – San Marino, SVN = Slovenia, SYR – Syria, TUN = Tunisia, TUR = Turkey, UKR = Ukraine

[http://www.nationsonline.org/oneworld/country\\_code\\_list.htm](http://www.nationsonline.org/oneworld/country_code_list.htm)