EUROBATS

Europe is faced with the need to tackle climate change and pollution and to find sustainable means to meet demands for energy generation. Thus the promotion of alternative methods for the production of energy such as wind power has been intensified. The low-emission production of wind energy brings benefits for the environment but on the other hand causes problems for wildlife, such as certain bat species. Therefore EUROBATS has developed guidelines for assessing potential impacts of wind turbines on bats and for planning, construction and operation of wind turbines in accordance with the ecological requirements of bat populations.

A first version of the guidelines was published in 2008, having the primary purpose to raise awareness amongst developers and planners of the need to consider bats and their roosts, migration routes and foraging areas. Guidelines should also be of interest to local and national consenting authorities who are required to draw up strategic sustainable energy plans. Furthermore, it was a base for national guidelines that were subsequently published in several countries.

A large amount of research has been carried out into the impacts of wind turbines on bats and the increased knowledge urged for this revision of the document. The revised guidelines are applicable to larger wind farm developments in urban as well as in rural areas, on the land as well as offshore. Some case studies were included to illustrate implementation of mitigation measures in some countries. Member countries should adapt these guidelines to their situation and prepare or update their national guidelines accordingly.

ISBN 978-92-95058-30-9
(printed version)

ISBN 978-92-95058-31-6
(electronic version)

EUROBATS

Publication Series
No. **6**

Guidelines for consideration of bats in wind farm projects
Revision 2014

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Rodrigues, L. Bach, M.-J. Dubourg-Savage, B. Karapandža, D. Kovač, T. Kervyn, J. Dekker, A. Kepel, P. Bach, J. Collins, C. Harbusch, K. Park, B. Micevski, J. Minderman (2015): Guidelines for consideration of bats in wind farm projects - Revision 2014. EUROBATS Publication Series No. 6 (English version). UNEP/EUROBATS Secretariat, Bonn, Germany, 133 pp.

Produced by	UNEP / EUROBATS
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Editors	Suren Gazaryan, Tine Meyer-Cords
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ISBN 978-92-95058-30-9 (printed version)
ISBN 978-92-95058-31-6 (electronic version)

Cover photo:
Fiona Mathews, UK

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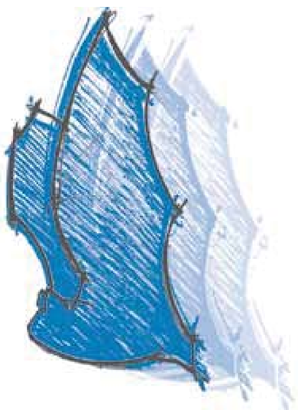
Contents

Foreword

Following Resolution 4.7, approved at the 4th Session of the Meeting of Parties of EUROBATS (Sofia, Bulgaria, 22–24 September 2003), the Advisory Committee of the Agreement was requested to assess the evidence regarding the impacts of wind turbines on bat populations. Also, if appropriate, to develop voluntary guidelines for assessing potential impacts on bats and for the construction of wind turbines, taking into account the ecological requirements of bat populations. In response to this request, an Intersessional Working Group (IWG) was established during the 9th Meeting of the Advisory Committee (Vilnius, Lithuania,17–19 May 2004). Some members of this IWG volunteered to prepare guidelines for assessing potential impacts of wind turbines on bats, which were adopted at the 5th Session of the Meeting of Parties (Ljubljana, Slovenia, 4–6 September 2006) as an Annex to Resolution 5.6. Those guidelines were published in EUROBATS Publication Series (Rodrigues *et al.* 2008). According to Resolution 6.12 of the 6th Session of the Meeting of Parties (Prague, Czech Republic, 20–22 September 2010), these guidelines (and any subsequently updated versions) should be the basis for national guidance to be developed and implemented, with consideration of the local environment.

The guidelines have subsequently been updated and the revised version (this document) was adopted at the 7th Session of the Meeting of Parties (Brussels, Belgium, 15–17 September 2014) as an Annex to Resolution 7.5.

Terms highlighted in bold and italics are included in the Glossary.



1 Introduction

Presently, there are 53 bat species occurring in the EUROBATS area and listed under the Agreement. Bats are legally protected in all European countries. Those occurring in the EU countries are protected by the Habitats Directive; all species are listed in Annex IV of this directive (Member States are required to take the requisite measures to establish a system of strict protection for them in their natural range) and some of them additionally in Annex II (species of community interest whose conservation requires the designation of special areas of conservation). In addition, most species are redlisted in one or more countries in Europe and on the IUCN Red List (IUCN 2014).

Europe continues to be faced with the need to tackle climate change and environmental pollution and to find sustainable methods to meet demands for power production. The commitment to low-emission energy generation leads to an increased promotion of alternative methods, *e.g.* wind power, following Kyoto Protocol and Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Furthermore, there is a growing public and political awareness to reduce or stop nuclear power production.

Wind turbines have been described as a problem for birds for many years (Winkelman 1989, Phillips 1994, Reichenbach 2002). More recently, many studies have established that wind turbines can have negative impacts on bats (*e.g.* Arnett *et al.* 2008, Baerwald & Barclay 2014, Rydell *et al.* 2010a, Lehnert *et al.* 2014). Bat mortality at wind turbines occurs due to collision and/or barotrauma (Arnett *et al.* 2008, Baerwald *et al.* 2008, Grodsky *et al.* 2011, Rollins *et al.* 2012).

A common pipistrelle (Pipistrellus pipistrellus) found dead with broken skull under a wind turbine (Germany). © H. Schauer-Weisshahn & R. Brinkmann

There are various reasons for bat presence, and resulting fatalities, around wind turbines. Clearly, the location of the turbines is an important variable (*e.g.* Dürr & Bach 2004). There are several European examples where an appropriate impact assessment has resulted in a wind turbine project being abandoned due to inappropriate siting with respect to bats. Annex 1 summarises studies done in Europe.

At low wind speeds, insect flight and bat activity occur at higher altitude, increasing the potential presence of bats near rotating blades. Security lights at the bottom of tower, the colour of wind turbines and acoustic effects are also suspected to attract flying insects and bats into the risk zone (Horn *et al.* 2008, Rydell *et al.* 2010b, Long *et al.* 2011).

It has been suggested that lights for civil aviation above the nacelle may also attract bats, but Bennet & Hale (2014) rejected this hypothesis. Furthermore, the outer extremities of the blades may reach speeds as high as 250-300 km/h, making them totally undetectable for echolocating bats (Long *et al.* 2009, 2010a). In addition to the risk of direct collision, the wake effect drastically modifies the air pressure in the vicinity of the rotating blades, enlarging the risk zone and causing fatal barotraumas to flying bats (Baerwald *et al.* 2008). Altogether 27 European bat species have been found as casualties beneath turbines (Annex 2). Adequate ***avoidance*** and ***mitigation*** measures taking these risks into account should be included in the environmental impact assessment and in the permit delivered by authorities before the operating phase (see Chapter 5).

A first version of the guidelines was published in 2008, having the primary purpose of raising awareness amongst developers and planners of the need to consider bats and their roosts, ***migration*** routes and feeding areas when they are assessing applications for wind turbines. Guidelines should also be of interest to local and national consenting authorities who are required to draw up strategic sustainable energy plans. Furthermore, it was a base for national guidelines that were subsequently published in several countries.

A large amount of research has been carried out into the impacts of wind turbines on bats and the increased knowledge justifies the update of this document. These guidelines are applicable to larger wind farm developments in urban as well as rural areas, on the land as well as offshore. ***Small wind turbines*** (SWT) are briefly mentioned, including an overview of the types of issues that need to be considered. Some case studies were included to illustrate implementing of ***mitigation*** measures in some countries. Member countries should adapt these guidelines to their situation and prepare or update their national guidelines accordingly.

Taking into consideration that Parties of the EUROBATS Agreement are committed to the common goal of conserving bats throughout Europe, in situations where bat ***migration*** routes cross borders, any ***strategic environmental assessment (SEA)*** or ***environmental impact assessment (EIA)*** of wind energy plans and projects with the potential for cross boundary impacts should seek international co-operation from other governments.

It has been suggested that bats may be attracted to insects around wind turbines: swarming ants caught in sticky insect trap (right photo) installed at the nacelle (left photo) in Sweden. © J. Rydell

2 General aspects of the planning process

Planning is usually organised at the local or regional level, and each locality or region has its own strategies to deal with a broad range of planning issues, including economic development, transport, housing, environment and energy. Planning policies/strategies regarding wind turbines need to address various environmental factors.

Bats should be considered in higher level regional planning when designating priority areas for wind energy. Modelling may be a powerful tool in some cases at this regional planning level (Roscioni *et al.* 2013, 2014, Santos *et al.* 2013).

Since bats are present almost everywhere and bat mortality at wind turbines is recorded in nearly all types of landscapes, it is likely that bats will be affected by most wind farm developments. Therefore, competent authorities issuing permits and decisions on environmental conditions for wind energy projects should require an appropriate impact assessment for bats (which may or may not be part of a formalised, legal ***SEA*** or ***EIA*** process) to be carried out before they grant permission for the plan or project. It is also necessary to adopt policies and practices that reflect the experience gained at existing wind turbine sites to ensure that bat populations are not threatened. The aim of an impact assessment is to assess possible impacts on local and migrating bat populations, as well as to design site-specific ***avoidance*** or ***mitigation*** measures and monitoring programmes.

Competent authorities can regulate the construction and operation of wind turbines by means of planning and operation conditions and/or planning obligations. These conditions and obligations can apply to a range of issues including size, layout, and location of the project, and temporal curtailment of turbines. When assessing planning applications for wind turbines and when drawing up conditions or obligations, planners should be mindful of impacts such as fatalities, disturbance to bats, severance of roosts from foraging areas, severance of ***commuting*** or ***migration*** routes, and/or habitat loss or damage. Authorities should also require that the impacts of the turbines on bat populations are monitored during the post-construction phase.

The strategy to reduce impacts should be based first on ***avoidance*** of impact, then minimisation (or ***mitigation***) of impacts, and finally ***compensation*** of residual effects, in that order. This is known as the ***mitigation*** hierarchy.

Every phase of wind turbine developments (pre-, during and post-construction) can have an impact on bats to a greater or lesser extent.

2.1 Site selection phase

Bat mortality at wind turbines occurs due to collision and/or barotrauma (Arnett *et al.* 2008, Baerwald *et al.* 2008, Grodsky *et al.* 2011, Rollins *et al.* 2012). The reasons that bats fly close to turbines and collide with them are numerous (see Chapter 1). Clearly, the location of the turbines in relation to bat habitat is an important factor (Table 1).

Table 1: Most important impacts related to the siting of wind turbines, from Bach & Rahmel (2004).

Impacts related to siting		
Impact	**Summer time**	**During migration**
Loss of hunting habitats during construction of access roads, foundations, *etc.*	Small to medium impact, depending on the site and species present at that site.	Small impact.
Loss of roost sites due to construction of access roads, foundations, *etc.*	Probably high or very high impact, depending on the site and species present at that site.	High or very high impact, *e.g.* loss of mating roosts.

Developers should consider locating wind turbines away from narrow bat ***migration*** and ***commuting*** routes as well as from areas where bats gather for foraging and roosting. Wind turbines may act as landmarks during ***migration*** or ***commuting***, which could exacerbate the problem of collision. Buffer zones should be created around nationally and regionally important roosts. The presence of habitats likely to be utilised by bats during their life cycle such as forests, trees, hedgerow networks, wetlands, waterbodies, watercourses and mountain passes should be taken into account. The presence of these habitats will increase the likelihood of bat presence. For example, large river corridors may serve as ***migration*** routes for bats such as *Nyctalus noctula* or *Pipistrellus nathusii*. However, even at wind farms in large, open, agricultural areas, high levels of bat mortality still occur (Brinkmann *et al.* 2011). Information on habitats and locations where wind turbines may have an impact would aid decision making.

In European countries, many wind turbines originally proposed at inappropriate locations where impacts on bats would have occurred have not subsequently been built due to appropriate impact assessment. For instance, wind turbine projects near the internationally recognized hibernacula of Montagne Saint-Pierre / Sint-Pietersberg at the Belgian-Dutch border were refused by authorities for bat conservation reasons.

Wind turbines should not be installed within all types of woodland or within 200 m due to the high risk of fatalities (Dürr 2007, Kelm *et al.* 2014) and the severe impact on habitat such siting can cause for all bat species. Mature broad-leaved forests are the most important bat habitats in Europe both in terms of species diversity and abundance (*e.g.* Walsh & Harris 1996a, b, Meschede & Heller 2000, Russo & Jones 2003, Kusch & Schotte 2007), but also young forests or monoculture conifer forest can support a considerable bat fauna (Barataud *et al.* 2013, Kirkpartrick *et al.* 2014, Wojciuch-Ploskonka & Bobek 2014). When wind farms are constructed within forests, it is often necessary to fell trees to clear ground for the construction of the wind turbines and supporting infrastructure. This could potentially result in a significant loss of roosts. Also, the consequent increase in forest edge habitats will improve foraging potential for bats (Kusch *et al.* 2004, Müller *et al.* 2013, Walsh & Harris 1996a, b), which could lead to an increase in bat activity closer to the wind turbines and further increase the risk of fatalities. Furthermore, such large changes in the habitat reduce the efficacy of the pre-construction studies in predicting the likely impacts of the development on bats.

In Northern European countries with high forest cover it may be necessary to include forests in the selection of sites for wind farms because of the lack of alternative locations. The importance of such areas for bat populations needs to be considered at a strategic level during the planning process. In these circumstances, particular attention should be paid to national guidance and to the planning process so that wind turbines are not sited in areas important for bats.

Wind farm in the Black Forest in Germany. A local population of common pipistrelle (P. pipistrellus) was affected by these wind turbines, as well as migrating species such as Leisler's bat (Nyctalus leisleri). © H. Schauer-Weisshahn & R. Brinkmann

Despite the recommendation that wind turbines should not be installed within all types of woodland or within 200 m, as clearly expressed in the previous version of these guidelines (and maintained and further supported in this version), wind farms have been allowed and are already operating in forests, albeit in a few European countries.

Therefore, reluctantly, guidance for survey (see Chapter 3), monitoring (see Chapter 4) and ***mitigation*** (see Chapter 5) for wind turbines in forests is provided in these guidelines, and following these strictly is even more demanding than for other more acceptable locations, because of the increased risks to bats in this type of siting.

Buffer zones of 200 m should also apply to other habitats which are specifically important for bats, such as tree lines, hedgerow networks, wetlands, waterbodies and watercourses (*e.g.* Limpens *et al.* 1989, Limpens & Kapteyn 1991, de Jong 1995, Verboom & Huitema 1997, Walsh & Harris 1996a, b, Kelm *et al.* 2014), as well as to any areas where high bat activity has been determined by impact assessment. Low levels of bat activity prior to construction cannot reliably indicate that there will be no impact on bats post-construction because bat activity can change due to the presence of the wind turbines and ***supporting infrastructure,*** as well as from year to year. The buffer distance should be measured from the outer range of blades, not from the axis of the tower.

2.2 Construction phase

Construction phase activities that are likely to have an impact on bats should be planned, whenever possible, for times of the day/year when they not impact bats. This requires local knowledge about the bat species present in the area, knowledge of the presence of hibernacula and maternity roosts, and an understanding of their annual life cycle. A typical year in the life of bats in Europe involves a period when they are active and a period when they are in hibernation. In central Europe generally bats are active from April to October and they are usually less active or in hibernation from November to March, but in the warmer south and in the maritime climate of the west, hibernation only occurs from mid-December to February (and in some mild winters some populations do not hibernate at all). Timing of activity and hibernation will vary according to geographical location (latitude and altitude) and also from one year to the next, depending on ambient weather conditions. Behaviour of some species will also play a part, as some cold-tolerant bat species are much more active during winter than others.

The construction of the wind turbines and all ***supporting infrastructure*** for the wind farm, including turbine bases, crane pads, temporary or permanent access roads, cables for grid connection and buildings, should all be considered as potential sources of disturbance or damage.

Construction should take place at appropriate times to minimise impacts of noise, vibrations, lighting and other related disturbance on bats. Construction activity should be clearly delineated in any plan to ensure operations are restricted to least sensitive times in that area.

Reports also mention the use of the nacelles by bats as roosts. Gaps and interstices of the turbines should therefore be made inaccessible to bats.

2.3 Operational phase

Depending on the locality and predicted level of impact (Table 2), consideration should be given to the use of planning and operational conditions on development permissions for wind farm projects to restrict the operation of wind turbines at times of peak bat activity such as during the autumn ***migration*** and ***swarming*** periods. Possible planning and operational conditions could include shutting down the turbines during the night during critical periods of the year. Examples are given in Chapter 5.

Table 2: Most important potential impacts related to the operation of wind turbines, adapted from Bach & Rahmel (2004).

Impacts related to operating the wind farm		
Impact	**Summer time**	**During migration**
Loss or shifting of flight corridors	Medium impact	Small impact
Fatalities	Small to high impact, depending on the species	High to very high impact

Wind turbines and their immediate surroundings should be managed and maintained in such a manner that they do not attract insects (suggested measures to accomplish this recommendation are indicated in 5.1.1.3).

2.4 Decommissioning phase

Competent authorities can include conditions and/or planning agreements in development consents that extend to the dismantling phase. Wind turbines can be decommissioned easily and rapidly. Consideration should be given to carrying out decommissioning at a time of year that minimises disturbance to bats and their habitats. In drawing up site restoration conditions authorities should consider the need to include conditions that are favourable to bats and their habitats.

2.5 Micro- and small wind turbines

Increasing numbers of ***small wind turbines*** (SWTs; also referred to as micro- or domestic wind turbines) are installed globally. No consistent definition of what constitutes an SWT is available and their size (both hub height and swept area) and design varies greatly, so their exact number is difficult to establish. However, the World Wind Energy Association (WWEA) reports that up to 650,000 SWTs of capacity <100 kW had been installed globally by 2010, generating 382 GWh annually (WWEA 2012). Because of their smaller size, compared to larger wind turbines, SWTs are often installed in a much wider range of habitats compared to their wind farm counterparts (RenewableUK 2012).

The evidence of effects on wildlife available for larger turbines cannot be directly extrapolated to SWTs (Park *et al.* 2013) because the latter are often installed in closer proximity to human habitation and also habitat features such as hedgerows, tree lines and water features (RenewableUK 2012), which are likely to be used by a diverse range of bat species. The limited evidence base currently available for the effects of SWTs on wildlife concerns a limited turbine size range. In some European regions (*e.g.* some federal states in Germany) the development of guidelines for SWTs is in progress, but in many areas no impact

assessments are required by the planning authorities. **The recommendations presented here are restricted to impacts of SWTs with hub height <18 m.**

Published experimental evidence specific to SWTs shows that bat activity (primarily *Pipistrellus* spp. and a smaller proportion of *Myotis* spp.) can be reduced by up to 50% in close proximity (1-5 m) of operating SWTs. This effect diminished at longer distances from turbines (20-25 m, Minderman *et al.* 2012), suggesting that bats avoid operating SWTs. A laboratory study by Long *et al.* (2009) showed that ultrasonic echoes returned from moving SWT blades were imperfect, potentially increasing collision risk by lowering detection of moving blades, and providing one possible mechanism for why bats avoid SWTs. Especially in areas where suitable habitat (*e.g.* feeding areas, ***commuting*** routes) is already limiting, disturbance or displacement effects as a result of such avoidance may have adverse effects on local populations. Species preferring open habitats, relatively high fliers, species able to exploit more cluttered habitats or those that frequently use "edge or gap habitat" are likely to be more at risk. This could include *Barbastella* spp., *Eptesicus* spp., *Plecotus* spp., *Rhinolophus* spp., *Pipistrellus* spp. and *Myotis* spp. Systematic studies on collision mortality estimates for SWTs have not been published. Minderman *et al.* (in review) found no carcasses during 171 systematic carcass searches at 21 SWT sites and within this sample only 3 owners (out of 212 surveyed) reported bat casualties. Combined with anecdotal evidence (BCT 2007) this shows that in some cases bat mortality should be a serious consideration.

In summary, from the evidence currently available, it is clear that (1) operating SWTs can cause disturbance and/or displacement of bats thereby limiting availability of potentially valuable habitat, and (2) bat mortality can be an issue at some sites.

3 Carrying out impact assessments

Wind turbine sites can have a number of impacts on bats. During their construction flight routes, foraging habitats, maternity roosts and hibernacula can be destroyed or be abandoned by bats, and during their operation turbines can kill bats due to collision or barotrauma. For this reason **it is necessary to conduct detailed bat surveys as part of impact assessments (which may or may not be part of a formalised, legal EIA or SEA process) for all planned wind farms.** The aim of impact assessments is to assess possible impacts on resident and migrating bats, as well as to propose site-specific protection or ***mitigation*** or ***compensation*** measures and monitoring programmes.

It is important to have a good knowledge, at a local level, of bat populations and of their biological and conservation status in each concerned site. This knowledge must be obtained by environmental impact studies. This will allow implementing appropriate ***mitigation*** measures.

During the last few years, a subject of debate has been whether there is a need for impact assessments relating to bats at all proposed wind farm sites or if it is appropriate to apply blanket mitigation measures without a prior impact assessment. Several studies have shown that, in the course of a year, most dead bats are found in late summer and autumn (Alcalde 2003, Arnett *et al.* 2008, Rydell *et al.* 2010a, Brinkmann *et al.* 2011, Amorim *et al.* 2012) and are frequently migrating species (Ahlén 1997, Ahlén 2002, Arnett *et al.* 2008, Rydell *et al.* 2010a, Brinkmann *et al.* 2011, Limpens *et al.* 2013). However, research has revealed, depending on the country and exact location, that resident bat populations can also be affected by wind turbines (Arnett 2005, Brinkmann *et al.* 2011). Bat fatalities also occur during spring and early summer, particularly in the southern parts of Europe (Zagmajster *et al.* 2007, Camina 2012, Georgiakakis *et al.* 2012, Beucher *et al.* 2013). Taking into account this information, impact assessments for bats should be carried out for all sites in order to identify if the proposed site location is appropriate, to adjust the site layout if necessary, to develop site-specific ***mitigation*** or ***compensation*** measures and to plan appropriate post-construction monitoring. This obligation was confirmed in the resolutions 5.6, 6.11 and 7.5 of the respective 5th, 6th and 7th Sessions of the Meeting of Parties of EUROBATS.

Wind farm built in 2002 (Aveyron, France) on a ridge at the edge of a beech forest. At that time there was little work on the impacts of wind turbines on bats and no EIA on bats was done. © M.-J. Dubourg-Savage

The impact assessment should identify the bat species, the times of year they are present and their spatial distribution (both horizontally and vertically) in relation to the proposed wind turbines. It should also correlate microclimatic conditions (such as wind speed, temperature, rainfall) with bat activity. This enables the design of a targeted ***avoidance*** and ***mitigation*** programme, which may include project abandonment, re-siting of some of the proposed turbines, site-specific use of blade ***feathering***, higher turbine ***cut-in wind speeds*** and shutting down turbines temporarily to avoid or reduce bat mortality respectively, as well as post-construction monitoring. Reliable data on bat activity are also necessary to wind farm operators, in order for them to calculate the economic risk of the wind farm.

Current generations of tall wind turbines allow economical energy production in nearly all landscapes. Irrespective of the landscape it is important to realise that taller wind turbines do not necessary reduce the bat mortality (Georgiakakis *et al.* 2012). On the contrary, larger rotors can increase mortality (Arnett *et al.* 2008). Studies have also shown that even in seemingly unsuitable bat habitats, such as large open agricultural plains, wind turbines can cause high bat mortality (Brinkmann *et al.* 2011). Wind farms on hill-tops and open coastal lowlands can have the same results (Georgiakakis *et al.* 2012, Bach *et al.* 2013b). When wind farms are constructed within forests the impacts can be exacerbated, particularly for resident bat populations (see Chapter 2.1).

The bat impact assessment methodology must take into account the summer as well as spring and autumn ***migration*** seasons, but also winter period in southern Europe, in order to avoid or mitigate the impacts satisfactorily. It is important that competent authorities consult renowned bat experts in order to assess potential impacts on bats when considering wind turbine applications (*e.g.* Bach & Rahmel 2004, Dürr & Bach 2004, Mitchell-Jones 2004, MEEDDM 2010, Brinkmann *et al.* 2011, SFEPM 2012, MEDDE 2014).

If more than 3 years elapse between the pre-construction surveys and the construction of the wind turbines, it may be necessary to repeat the pre-construction surveys. This point should be highlighted in national guidelines or legislation.

The following section provides information on non-statutory impact assessments. Developers will also need to undertake formal assessments to meet national legislation or national requirements under ***EIA*** and ***SEA*** regulations where appropriate. Since bat mortality occurs in nearly all landscapes, an impact assessment will generally be required before a competent authority can make a decision on whether to grant permission for a wind energy project.

Due to knowledge gained from recent research and technical developments during the last few years, the survey design recommended in this document is different from previous versions.

Goals of the impact assessment in relation to bats

A list of questions should be answered in a bat impact assessment in order for the potential impacts of a wind farm on bats to be adequately assessed, as follows:

- Which bat species are present at the location and in its vicinity?
- What are the activity levels of the species present and how does activity vary throughout the year (to take into account the full cycle of bat activity)?
- How are the bats using the landscape at the location and in its vicinity (are there maternity roosts, hibernacula, flight paths, foraging areas and/or ***migration*** routes)?
- What are the expected impacts of the project on bats and their habitats pre-, during and post-construction (*e.g.* disturbance; destruction or loss of function of roosts, commuting routes or foraging sites; and mortality) and what is their significance?
- If significant impacts are expected, what site-specific measures will be applied to avoid, mitigate and compensate for these impacts?
- What method, scale and schedule of post-construction monitoring should be applied to the project?

3.1 Pre-survey assessment

The aim of the pre-survey assessment, as a first step, is to identify which species are known from the local area and which landscape features could be used by bats. The results of this assessment will inform the survey design. Given the impacts that wind turbines can have on bats, it is recommended that a pre-survey assessment should be undertaken for all new ***onshore*** and ***offshore wind turbine*** proposals. The pre-survey assessment is a preliminary step to gather evidence about the likely impact of the proposal on bats, but it cannot be used as a substitute for the impact assessment surveys. It can, however, help the developer in his decision concerning the suitability of the site for wind turbine construction and help to design properly a detailed survey.

Consideration should be given the following as part of the pre-survey assessment.

Collation and review of existing information

A range of information sources should be reviewed to identify potential habitats for bats at the location and in its vicinity and to identify existing records of bats in the area. These should include:

- recent aerial/satellite photographs/ maps/habitat survey maps,
- species distribution maps,
- databases of protected areas (*e.g.* Natura 2000 sites),
- records of known roosts and bat sightings (for offshore sites this could include records from oil rigs, lighthouses and other open sea or coastal records),
- existing knowledge of bird ***migration*** routes as they could provide information on bat ***migration***,
- existing knowledge of European bat ***migration*** data,
- papers and reports on ecology of bats.

Where appropriate, consultations with key organisations that hold data on bats should also be undertaken. These organisations could include:

- local bat groups,
- biological records centres,
- wildlife trusts,
- nature conservation organisations,
- bat conservation trusts,
- natural history museums,
- university research organisations,

Collision risk level for European bat species

Under European legislation, particularly the Habitats Directive, all bats are protected individually, which means that it is unlawful to kill a bat intentionally.

Fatality research studies during the last few years have shown that, due to their different behaviour and flight style, bat species are affected differently by wind turbines (Rydell *et al.* 2010a, Brinkmann *et al.* 2011, Ferri *et al.* 2011, Amorim *et al.* 2012, Camina 2012, Georgiakakis *et al.* 2012, Santos *et al.* 2013). Bat species that fly and forage in open space (aerial hunters) are at high risk of collision with wind turbines (Bas *et al.* 2014). Some of these species also migrate long distances at high altitude, which also increases collision risk (*e.g. N. noctula, P. nathusii*). In contrast, gleaning bats, which tend to fly close to vegetation, have a lower risk of colliding with wind turbines.

In Table 3 the collision risk for European and Mediterranean bats species to which EUROBATS applies for wind turbines in open habitats is shown. Where wind turbines are sited in broadleaved or coniferous woodlands or on woodland edges, this may significantly increase the collision risk for some species.

Table 3: Level of collision risk with wind turbines (not micro- and small wind turbines) for European and Mediterranean bat species to which EUROBATS applies (state of knowledge: September 2014).

High risk	Medium risk	Low risk	Unknown
Nyctalus spp.	*Eptesicus* spp.	*Myotis* spp.**	*Rousettus aegyptiacus*
Pipistrellus spp.	*Barbastella* spp.	*Plecotus* spp.	*Taphozous nudiventris*
Vespertilio murinus	*Myotis dasycneme**	*Rhinolophus* spp.	*Otonycteris hemprichii*
Hypsugo savii			*Miniopterus pallidus*
Miniopterus schreibersii			
Tadarida teniotis			

* = in water rich areas ** = exclusive *Myotis dasycneme* in water rich areas

- local, regional or provincial authorities,
- consultants that have worked in the area.

It is recommended that for land-based wind turbines the pre-survey assessment should consider all available data on bats within at least a 10 km radius of the wind turbine locations. In some cases a larger radius may be appropriate (*e.g.* in the case of important colonies of species which commute long distances to foraging sites (Annex 3)).

Migration routes over land and offshore should also be considered. Particular consideration should be given to bat ***migration*** routes when wind turbines are proposed close to prominent landscape features such as river valleys, upland ridges, upland passes and coastlines. For offshore proposals, the location of the wind turbine in relation to migration routes between principal land masses and islands should also be taken into account, especially where there are records of bats on islands, oil rigs, *etc.*

A wind farm in Bouin (Vendée, France), on the Atlantic coast, where migrating bats are regularly found dead under the wind turbines. The species concerned are mainly Nathusius' pipistrelles (P. nathusii), noctules (N. noctula) and common pipistrelles (P. pipistrellus). © F. Signoret/LPO

This assessment can exclude areas which are inappropriate locations for wind turbines from a bat perspective (*e.g.* vicinity of important bat roosts, areas protected and designated for bat conservation, broadleaved or coniferous woodlands, 200 m buffer zones from woodland edges, tree lines, hedgerow networks, wetlands, waterbodies and watercourses).

3.2 Survey

3.2.1 Survey design

Survey design will differ depending on the proposed location of the wind turbines and the results of the pre-survey assessment. Consideration should be given to:

- the spatial scale of the survey, which should closely reflect the size and number of wind turbines and ***supporting infrastructure*** such as crane pads, access roads and grid connections,
- the potential use of the site by bats (informed by the pre-survey assessment),
- how the above may affect the timing and effort of survey work.

Larger wind turbines blades have a typical rotation zone of between 40 and 220 metres above the ground and therefore consideration should be given to the height at which survey work should take place. Such turbines are most likely to affect high flying species, although it is recommended that all species are considered and assessed within the overall impact assessment.

Whenever possible (for example, if there is a meteorology mast erected or planned for the site) it is recommended that the activity of bats should be recorded at the height of the collision risk zone, *e.g.* at the bottom of the blade swept zone of a wind turbine.

Meteorology mast with automated bat detectors installed for recording of bat activity at the height of the collision risk zone, France. © J. Sudraud

Given the potential impacts of wind farms on bats, it is essential (for an accurate and complete impact assessment) to take into account the full cycle of bat activity throughout the year. This includes investigating the possibility of hibernation roosts being present and surveying them if they are. The cycle of bat activity can start in mid-February and end in mid-December, but is likely to be shorter in northern parts. In some regions of southern Europe (*e.g.* coastal Greece and Montenegro), hibernation may be absent and surveys should therefore continue all year round. The intensity of survey work throughout this period may also vary depending on the location (*e.g.* due to the presence of migrating bats) of the proposed wind turbines and the potential use of the site by bats.

Surveys should provide information about roosting, foraging and ***commuting*** by local bat populations, along with identifying bat ***migration*** through the area. As a consequence it is recommended that a greater intensity of survey work should be undertaken in spring and autumn when bats are migrating, because this activity is more difficult to observe, tends to be more unpredictable and is dependent on weather conditions. The timing of such surveys could be guided by local knowledge about when hibernating bats emerge, when maternity colonies disperse, when mating begins and when ***swarming*** has been observed in the area.

3.2.2 Survey methods

3.2.2.1 Land-based wind turbines

Surveys of proposed wind turbine sites should employ the best methods and equipment for the relevant habitat. This generally includes the use of ***manual bat detectors*** and ***automated bat detector*** systems. Investigation of potential roost sites should also be conducted. In particular, in areas with a large coverage of limestone karst, previously unknown roosts are frequently discovered. When wind farms or infrastructure associated with wind farms are planned in forests, more intensive methods are required, such as bat detector surveys above the canopy, trapping to verify species and status (using mist nets for bats and/or harp traps) and, exceptionally, radio tracking to find tree roosts.

Due to the range of heights of new wind turbines, existing structures (towers or masts) at the study site should be used to deploy automatic detection systems at the relevant heights (preferably at the proposed blade swept zone) whenever possible. Weather conditions should always be monitored and recorded whilst conducting surveys (temperature, precipitation, wind).

For wind farm ***repowering*** and extension studies, existing wind turbines can be used to install ***automated bat detector*** systems in the nacelle (see Brinkmann *et al.* 2011).

Experiments with ***automated bat detectors*** attached to kites or balloons (*e.g.* Fenton & Griffin 1997; Sattler & Bontadina 2006; McCracken *et al.* 2008; Albrecht & Grünfelder 2011) have shown that these methods provide data of limited use. This is because bats appear to behave differently at height when structures (such as wind turbines and masts) are present in comparison to when these structures are absent. In the absence of structures, bats appear to be rare at height (Grunwald & Schäfer 2007, Ahlén *et al.* 2009, Albrecht & Grünfelder 2011).

Automated bat detector attached to a balloon for bat activity survey during EIA. © J. Sudraud

It is generally assumed that ground data can be used to assess the activity at nacelle height because there are several studies showing a correlation between the two variables (*e.g.* Behr *et al.* 2011, Bach *et al.* 2013). However, in some situations no strict correlation was found (Collins & Jones 2009, Limpens *et al.* 2013). Wind farm surveys should, therefore, record bat activity at least within the blade swept zone.

It is recommended that intensive activity surveys should be undertaken within a 1 km radius of each proposed wind turbine throughout the pre-construction survey period. If the locations of the wind turbines are not yet specified, the survey should cover a 1 km radius around the proposed area. Surveys should cover the wind turbine locations and all habitats on site that are likely to be used by bats. Searches for maternity and hibernation roosts should be undertaken within a 2 km radius (depending on the expected species and the habitat(s) present) and existing known roosts should be checked within a 5 km radius; if important roosts are found, they should be monitored in subsequent years.

To provide an indication of ***migration*** routes, an intensive survey, to identify an increase in migratory species, should be undertaken in spring and late summer / autumn.

Wind turbines should, as a rule, not be installed within all types of woodland or within 200 m due to the risk that this type of siting implies for all bats. German studies have shown that fatalities have been recorded up to 95 m from a wind turbine (Niermann *et al.* 2007) and that *N. noctula* was most often killed at wind turbines that were at a mean distance of 200 m from wooded areas (Dürr 2007).

The setting of wind turbines in woodlands is highly dangerous for bats and therefore not recommended and criticized by the present guidelines. © H. Schauer-Weisshahn & R. Brinkmann

Where wind farms are proposed in forests (despite advice to the contrary), the issue of bats flying at height above the tree canopy should be claimed. Because bat activity within and above the forest can differ significantly (Kalcounis *et al.* 1999, Collins & Jones, 2009, *Plank et al.* 2011, Bach *et al.* 2012, Müller *et al.* 2013, Hurst *et al.* 2014, Grzywinski *et al.* 2014) and it may not be possible to detect foraging and migrating bats above the trees from the ground, special attention should be given to recording bat activity above the canopy (see Bach *et al.* 2012, Müller *et al.* 2013).

The focus should be on high flying species that forage or migrate above the canopy (*e.g. Pipistrellus* spp., *Hypsugo savii*, *Barbastella* spp., *Eptesicus* spp., *Vespertilio murinus* and *Nyctalus* spp.) and tree roosting species like *Plecotus* spp., *Myotis bechsteinii* and *Myotis nattereri*.

3.2.2.2 Offshore wind turbines

For several years we have known that bats cross open seas during ***migration*** (Ahlén 1997, Boshammer & Bekker 2008, Ahlén *et al.* 2009, Hüppop 2009, Bach & Bach 2011, Frey *et al.* 2011, 2012, Meyer 2011, Skiba 2011, Bach *et al.* 2013a, Eriksson *et al.* 2013, Poerink *et al.* 2013, Seebens *et al.* 2013, Rydell *et al.* 2014, BCT 2014). For this reason, ***offshore wind turbines*** should be surveyed in the same manner as land-based turbines (Bach *et al.* 2013c, Cox *et al.* 2013). Clearly, this presents more of a challenge than land-based turbines because surveys will have to be undertaken from boats, lighthouses, buoys, *etc.* Surveys for offshore wind farms should be concentrated in spring (April-June) and autumn (August-October/November), unless data (such as bats found on nearby oil rigs, islands, *etc.*) indicate their presence at any other time of the year. During a monitoring study at a research platform Seebens *et al.* (2013) found that resident bats can hunt at least 2 km out to sea during the summer months. Therefore, at proposed nearshore wind farm sites bat activity should also be assessed during the summer months.

Offshore wind farms, such as this one in Sweden, can have negative impacts on bats when sited on their migration routes. © L. Bach

3.2.2.3 Micro- and small wind turbines

For proposed sites where rare or vulnerable bat species are known to be present, or within 25 m from large hedgerows or treelines, broadleaved or coniferous woodlands or woodland edges, single mature trees (particularly when suitable for roosts), watercourses, ponds or lakeshores, or buildings (where suitable for roosts), surveys of bat activity and roosts are required:

a. At least two site visits with ***manual detectors***, covering the maternity period, to check for the presence of roosts within 50 m of the SWT. One of these should be a dawn visit.
b. Continuous automated bat detector survey during the entire season (April-September in most areas) using appropriate detectors that are able to detect and distinguish all species present.

3.2.3 Survey effort

Depending on the local geographical conditions and on the species hibernating in the region, dates for the beginning and the end of the bat active period (and thus the survey year for acoustic detection) will vary. ***Migration*** may last longer in some regions and hibernation is shorter in southern Europe than in northern parts of the continent. It may therefore be necessary to extend bat activity surveys from mid-February to the end of November (or even longer in southern Europe, where hibernation may be absent). Survey effort will also vary. Although the collision risk in, for example, Germany seems to be lower in spring than in late summer and autumn, it is important to recognize whether the area plays an important role for spring bat ***migration***. Survey effort should be tailored to the regional conditions, scale of the individual development and the potential impacts. Monitoring studies have shown that bat activity can change by more than 50% from one night to the next, even when the recorded weather conditions are the same. The reason appears to be changing insect concentrations or land use (mowing a meadow, cattle on another grassland, *etc.*).

Therefore it is crucial to conduct surveys on an adequate number of nights from the different stages of bat activity (for dates see 3.2.4.1 e). These stages are as follows:

(i) ***commuting*** between post-hibernation roosts,
(ii) spring ***migration***,
(iii) activity of local populations, checking for flight paths, foraging areas, *etc.* and concentrating on high flying species,
(iv) dispersal of colonies and the start of autumn ***migration***,
(v) autumn ***migration***, mating roosts and territories

(vi) ***commuting*** between pre-hibernation roosts (late hibernating species of Southern Europe).

3.2.4 Type of survey

3.2.4.1 Onshore survey

a) Investigation of important roost sites

New roosts should be searched for within a 2 km radius (the exact radius depending on the expected species and habitat(s) present) and known roosts should be checked over at least a 5 km radius to assess stages (iii) and (iv) (see above) of bat activity (May to October). Potentially important roosts (including maternity and hibernation roosts as a minimum) should be subject to detailed survey. Additional help during the search can be gathering information from the local residents and speleologists (in karst areas). Possible important sites can be determined based on bat traces, presence and abundance of recorded bats.

b) Bat detector surveys on the ground

1. ***Manual bat detector*** surveys at ground level (transects) should be undertaken throughout the bat active season to determine a ***bat activity index*** (number of bat contacts per hour) for the study area (encompassing at least 1 km radius around the planned siting of the wind farm). The detector system used should cover the frequencies of all bat species that may be present. It should also allow the determination of all relevant species or species groups. Acoustic observation should be accompanied with visual observation as it can yield a lot of important additional data, such as spatial identification of ***commuting*** routes, certain roost types and ***swarming*** sites, and also to enhance species identification. In the results the percentage or number of feeding buzzes should also be recorded. During the manual bat detector survey an ***automated detector system*** that can link to GPS-files should be used to verify the location of registered bat contacts.

2. ***Automated bat detector*** surveys using high-resolution ultrasound recorders or frequency division detectors should be carried out during each manual detector survey visit, ideally at each proposed wind turbine location, throughout the bat active season, to determine a site specific ***bat activity index*** (number of bat contacts per hour). If this is not possible, the ***automated bat detectors*** should be placed on a representative number of turbine sitings in each type of habitat, relief and topography present (for example: hill tops and valleys). In the results, the percentage or number of feeding buzzes should also be recorded. The detector system used should cover the frequencies of all bat species that may be present. It should also allow the determination of all relevant species or species groups. Within forests, continuous ***automated bat detector*** monitoring (at least one ***automated detector system*** for 2–3 planned wind turbines) should be conducted above the canopy, during the whole season.

3. At least one high-resolution ultrasound recorder or frequency division detector and recording system should be installed in the survey area for monitoring bat activity continuously during the whole season. Depending on the number of proposed wind turbines, the size and the structural diversity of the survey area, more than one detector and recording system may be necessary.

c) Activity surveys at height

Automatic recording bat detector (high resolution ultrasound recorders or frequency division detectors – see below) should be placed on meteorology masts, wind turbines or other suitable structures in the vicinity of the proposed wind farm to establish a ***bat activity index*** and species composition throughout the bat active period

Automated detector system installed at a meteorology mast in France. © EXEN

where possible, at least during key periods of the year (ideally during the same period as ***automated detector*** systems at ground level). However, caution should be applied when comparing ground results and height results monitored by different types of bat detector (the range and accuracy of detectors differs between systems). Therefore, the same detector systems should be used both at ground level and at height to produce comparable data.

d) Equipment requirements

At present there is a vast range of different brands and types of detector systems available on the market ranging from heterodyne detectors and frequency division detectors to full spectrum detectors which can be hand held during the survey visit and used as an automated system. In order to obtain representative and comparable data, it is very important to use equipment of the correct specification and condition.

The ***manual bat detector*** system used during the survey must adequately cover the frequencies used by all high and medium risk species. In some areas this might be fulfilled by using heterodyne detectors with the possibility of time expansion, but in most areas it is recommended that a full spectrum, time expansion, or frequency division detector system is used. The detector and microphones must be of good quality. It should be possible to back up the system with recorders (ideally including a GPS receiver) in such quality that thorough analysis of the recorded ultrasonic calls afterwards is possible.

The automated bat registration system used should be a full spectrum detector system including frequency division detectors, with microphones of good quality. The microphone sensitivity needs to be checked and if needed calibrated every year. Microphones with considerably deteriorated parameters (reduced sensitivity), *e.g.* due to humid environment, should not be used.

In all surveys, the detector system and its settings must be standardized for each project. These settings should be recorded and provided in any subsequent survey reports, as they can influence results.

e) Timing of survey

Manual bat detector surveys from the ground

The number and seasonal distribution of the survey visits will depend on the local geographical conditions and on the presence of species with a very short hibernation period. All survey visits should be undertaken in appropriate weather conditions (ideally no rain (although short showers are acceptable), no fog, wind <5 m/s, temperature >7°C).

One "survey visit" can consist of several nights that are needed to cover the whole study area:

- 15 Feb – 15 Apr[1] (stage i): one survey visit every 10 days, first half of the night from sunset for 4 hours,
- 15 Apr[2] – 15 May (stage ii): one survey visit every 10 days, *i.e.* two times for the first half of the night (from sunset for 4 hours) and 1 whole night in May,
- 15 May – 31 Jul (stage iii): one survey visit every second week, always a whole night,
- 1 – 31 Aug (stage iv): one survey visit every 10 days, always a whole night; during this stage one should also search for mating roosts and territories,
- 1 Sep – 31 Oct (stage v): one survey visit every 10 days, two whole nights in September, first half of night from sunset for 4 hours in October. During this stage one should also search for mating roosts and territories. At the end of September and October at large lakes or along rivers on the European continent, *N. noctula* have been noted in large numbers hunting in the afternoon up to 100 m above the ground. Therefore the survey should start 3-4 hours before sunset, where this behaviour of *Nyctalus* ssp. is suspected, and be continued for 4 hours after sunset,
- 01 Nov – 15 Dec[2] (stage vi): one survey visit every 10 days (if weather conditions are appropriate), first half of night from half an hour before dusk for 2 hours.

Automated bat detector survey at the proposed wind turbine locations

Ideally, at least in one night during each ***manual detector*** survey visit, an automated bat detector system should be placed at the proposed location of each wind turbine. If not possible, it should be placed on

[1] Applies mainly to southern Europe, for *Miniopterus schreibersii, Rhinolophus euryale, Myotis capaccini* and *Pipistrellus* spp.

[2] Applies mainly to places where there is no hibernation or where some species are already active.

a representative number of turbine sitings in each type of habitat, relief and topography present (for example: hill tops and valleys).

Automated bat detector with microphone mounted at 2 metres above the ground at the planned location of wind turbines. © J. Sudraud

Continuous automated bat detector monitoring

An ***automated detector*** system (see 3.2.4.1 b. 3) should be installed in the survey area to monitor bat activity during the whole season (the start and end of which will depend on the regional conditions). The system should be set to record bat activity from one hour before sunset to one hour after sunrise. In some regions, *e.g.* along rivers and at lakes, bats may hunt during the afternoon after September. In these situations, detector systems should be set to record bat activity from at least 3-4 hours before sunset to one hour after sunrise.

Within all types of woodland

As previously stated, wind turbines should not be installed within woodland or within 200 m due to the high risk of fatalities. However, in countries where this is still allowed, in addition to the manual detector surveys described above, bat activity should be monitored above the canopy using an ***automated detector*** system. The system should be set to record bat activity at the proposed turbine locations during the bat active season, from one hour before sunset to one hour after sunrise. It is also recommended to use mist nets, in order to confirm the presence of species that are very difficult to detect or recognise by acoustic methods.

Mist-nets can be used to confirm the presence of some species: B. barbastellus caught during survey in Macedonia. © N. Micevski

3.2.4.2 Offshore survey

For offshore wind farms it is more difficult to survey bat activity. Few methods have been developed and robustly tested for surveying in this environment (Ahlén *et al.* 2007, 2009, Meyer 2011, Sjöllema 2011, Seebens *et al.* 2013). Official guidelines for offshore bat surveys have been developed for Germany (Bach *et al.* 2013c), covering the Baltic Sea. Although Denmark, Sweden and Poland have started to include bat surveys for offshore proposals, there are no official guidelines for these countries. Experience in the Baltic area suggests that it is most productive to combine observations from both the land and the sea. Bruderer & Popa-Lisseanu (2005) developed a system that has the potential to distinguish bats and birds in tracking radar but it requires further studies before it can be used systematically.

Surveys for offshore proposals should focus on the ***migration*** period. Near-shore surveys should also include summer activity.

a) Surveys from land should:

- be at prominent land marks like headlands, thought to be locations where bats leave the shore heading in the direction of the planned wind farm,
- include bat detector surveys (manual and automatic) from the ground,
- include long-term automatic surveys with a bat detector mounted on a lighthouse or any other suitable structure (for ***bat activity index*** and groups of species),
- include the use of infrared or thermal imaging camera whenever available.

b) Surveys at sea should:

- comprise boat surveys (transects or stationary anchor points) in the area of the proposed wind farm (it may be possible to combine boat transects with nocturnal bird surveys),
- include continuously automated bat detector monitoring on oil platforms, research platforms and buoys,
- include, if possible, surveys from regular night ferries crossing between two landmark points that are suspected to be important for bat ***migration*** (*e.g.* Puttgarden-Rødby or Bornholm-Sassnitz in the Baltic Sea, Dover-Calais in the English Channel),
- include, if possible, tracking radar from a coastal point in combination with boat transects.

c) Timing of surveys:

Boat surveys for offshore wind farms should be carried out from the beginning of April until the beginning of June, and from the beginning of August until the middle or end of October (depending on the locality) at least twice a week. For near-shore wind farms it may also be necessary to cover the summer period (June/July) to detect resident bats foraging offshore.

Continuously automated bat detector monitoring should cover both ***migration*** periods and (for near-shore wind farms) also June/July.

3.2.5 Survey report and evaluation

As the survey report is aimed at people who have little or no knowledge of bat ecology and bat surveys, the report should set out:

- the species known to be present in the geographical and administrative area and their status,
- the methods and equipment used during the surveys (with equipment settings, when these may influence the results) and their limitations,
- the survey dates, survey start and end times and weather conditions recorded along with corresponding sunset and sunrise times and the reason these dates and start times were chosen,
- the species identified during the survey and their observed behaviour (passing through, foraging, ***swarming***, ***migrating***) and habitat use, as well as the date and time of observation. The results should be presented in a format that enables the reader to interpret the data. Data could be presented, for example, by species recorded, by bat activity through the year, by activity through the night, or by activity at different heights,
- maps to illustrate the spatial and temporal distribution of bat activity of different species or groups of species,
- the difference in bat activity in relation to detectability (Annex 4)
- the differences in bat activity according to different seasons and night phases,
- the differences in bat activity at different heights, if a weather mast (or another technique) has been used,
- the likely impacts of the wind farm on bats,
- ***avoidance***, ***mitigation*** and ***compensation*** measures,
- suggested scheme of post-construction monitoring and the proposed impact of various options of its results on the scope of the ***mitigation/compensation*** measures.

Bat activity should be presented as activity indices (*e.g.* bat contacts/hour or bat activity units/hour), calculated for instance for survey visits, nights and average for different periods of bat activity like spring, summer and autumn. Activity indices of individual species, species groups and of all bats can then be subject to analysis. The evaluation should account for local and regional variations in legal protection and conservation status. Impacts may differ according to different turbine layouts or where habitats provide different functions for the species present. For some species (*e.g. N. noctula* and *P. nathusii*) there is a positive correlation between activity at ground level and activity at nacelle height but this is not the case for *P. pipistrellus* (*e.g.* Brinkmann *et al.* 2011).

A ***conflict analysis*** should then be presented for each wind turbine for each species present, and the mortality risk should be assessed and presented. Every wind turbine siting and the entire ***supporting infrastructure*** must be evaluated accordingly and proposals made to limit the impacts. The approach should be to apply measures to avoid impacts in the first instance, but where this is not possible to mitigate or, lastly, compensate for them.

For more details about reporting and analysis see Dürr (2007) and Kepel *et al.* (2011).

3.3 Repowering / Extension

For these projects it is necessary to combine bat activity surveys including both ***manual bat detector*** surveys (see 3.2) and ***automated bat detector*** surveys at nacelle height. In addition, for a wind farm extension the surveys should be combined with a search for bat fatalities at the existing wind turbines. The activity surveys (***manual bat detector*** survey visits and ***automated bat detector*** survey at each planned wind turbine) should take into account the proposed locations of any new turbines. The monitoring methods proposed in Chapter 4 are to be applied during the whole bat activity season. A reduced number of manual survey visits in summer and ***migration*** time is recommended. This is due to the fact that the emphasis lies on the continuous ***automated bat detector*** survey at nacelle height; the ground based detector survey completes the picture of bat activity in the vicinity of the wind farm.

Measurement of bat activity at nacelle height from neighbouring similar wind turbines in combination with the search for bat fatalities, will enable an assessment of existing collision issues and a better prediction of the collision risk at the new planned wind turbines than a manual survey at ground level only. If the size of the new wind turbines is not similar to the original wind turbines, as is usually the case in ***repowering*** projects, a fatality search should be carried out in order to compare the effect of different sized turbines.

Microphone installed above the nacelle for automated bat detector survey. © J. Rydell

4 Monitoring the impacts

Monitoring of operating wind farms is essential to increase our understanding of their potential impacts on different bat species. Although assessing the cumulative effects of existing and proposed wind farms and of other infrastructure development is usually required in formal ***EIA***, only individual wind farms have been monitored to date. Specifically, there are no studies of the cumulative impacts of wind farms placed along a ***migration*** route. Nevertheless, it would be very important to develop methodologies to assess the cumulative effect; some researchers (*e.g.* Barclay com. pers.) support the idea that bat mortality should be estimated per MW and not per turbine.

To assess the impacts of wind turbines on bats, studies should use standardised methods to produce comparable results.

Monitoring the impacts of wind energy on bats will only have a scientific value if it takes into account the original status of bat populations in the area before wind farm installation.

At least three years of monitoring during the operational phase of the wind farm are necessary to assess the impacts on resident species (attractiveness, changes in behaviour and mortality) and on migrating species (changes in mortality) and to highlight possible yearly variations. According to the results, another 3 years may be necessary to gain a complete understanding of the changes.

A comprehensive monitoring scheme should focus on both activity levels and mortality rates. The post-construction activity monitoring will assess changes in bat activity and will also help to understand the results of mortality monitoring.

Wind park Puschwitz in Saxony, Germany: 10 wind turbines are situated in a hilly landscape with highly diverse habitats, including many water courses. Between 2002 and 2006, 76 dead bats were found under the turbines, consisting largely of noctules (N. noctula), Nathusius' bats (P. nathusii), common pipistrelles (P. pipistrellus) and parti-coloured bats (V. murinus). © M. Lein

4.1 Monitoring of activity at nacelle height

Manual acoustic monitoring on the ground may be carried out during construction to evaluate if building wind turbines brings any significant disturbance to bats and to their roosts, but during the operation phase of the wind farm monitoring of activity at nacelle height will be more important. It should last at least three consecutive years and cover the annual cycle of bat activity (spring until autumn, depending on the geographical region). It is important to install bat detector microphones at nacelle height to record bat activity in the area of greatest potential impact, the area swept by the rotor blades. In order to obtain standardised and therefore comparable data, bat detectors must allow identification of calls down to species or group of species level. Acoustic monitoring should follow Brinkmann *et al.* (2011). The following technical information should be described in the reporting:

- detector type and analysis software,
- sensitivity parameters of the detector,
- location of the detector within the nacelle,
- working and failure periods of the detector.

Mages & Behr (2008a, b) give examples about erecting detectors into turbine nacelles and refer to some of the constraints (*e.g.* noise problems).

The recorded bat activity should be analysed taking into account the season, the time of night and weather data such as wind speed and air temperature. Beside the species-specific detectability, several different detector systems are available and used nowadays. Since the detector systems are highly variable (Adams *et al.* 2012) and different settings can be changed at each detector system, activity data as contacts/hour are different between different systems and/or settings. Also the sensitivity of a microphone, which may be significantly reduced over time, especially under the influence of humidity, can substantially affect the results obtained. To compare activity data from automatic recordings, some detectability coefficient tables can be developed for most commonly used detectors. An example of such a table is supplied in Annex 4.

This enables the development of a strategy to mitigate impacts by, for example, curtailment of the turbines at specific times of the year and night using an algorithm that predicts risk of fatalities from these data.

Remote microphone installed at the nacelle's bottom (above) and connected to automated bat detector inside the nacelle (below). © L. Bach

Thermal imaging cameras give valuable data on this issue (*e.g.* Horn *et al.* 2008), so if possible they should be used. If the efficiency of tracking radar is proven, this too can be considered.

Putative ***migration*** routes should be assessed by checking for the presence of bats along bird ***migration*** routes in the area, analysing automatic recording of ultrasound at height, and performing late afternoon and dawn observations (visually and, if possible, with an infrared camera; ideally with a thermal imaging camera).

4.2 Monitoring of mortality

As mortality is the greatest impact that wind turbines have on bats and on some bat populations, it has to be eliminated or at least reduced to a minimum to comply with the obligations of the ***Habitats Directive*** and of national laws on protected species. The main methods currently used to reduce or avoid mortality are blade ***feathering***, increased turbine ***cut-in wind speeds*** and shutting down turbines temporarily during higher risk times of the night or year. However, the increase of the ***cut-in wind speed*** may be not 100% efficient because some species, especially migrating ones, will still fly in wind speeds exceeding 10 m/sec (Hurst *et al.* 2014). Monitoring of mortality is therefore still necessary to assess the efficacy of these measures. The methodologies are discussed extensively in Brinkmann *et al.* (2011) and Limpens *et al.* (2013) and are summarised here.

The number of fatalities can vary significantly according to the siting of the wind farm and the species present. It is important to be aware that the number of carcasses found does not equate to the real number of bats that are killed. This is because the count process is biased due to several factors, such as: removal of casualties by scavengers or predators; searcher efficiency (which depends, among other factors, on the type and height of ground cover underneath the turbines – *i.e.* detectability); and effort invested in the survey (monitoring schedule, time interval and size of the searched area). Additionally, some bats fly away and die later on due to internal injuries (Grodsky *et al.* 2011); however, this situation is not quantifiable. Therefore, mortality monitoring will consist in three stages: carcass searches, trials to obtain correcting factors for the biased estimates, and estimation of true mortality rates.

4.2.1 Searching for bat fatalities

a) Search plot size

Ideally, the search process should take place around the wind turbine within a radius equal to the total height of the wind turbine, as bats that collide can be blown away from the turbine by high winds (Grünkorn *et al.* 2005, Brinkmann *et al.* 2011). However, in most cases this is impractical due to the height of vegetation or other obstacles. In this situation, it is advisable to search a smaller surface area that can be kept clear of vegetation all year round or at least covered with only very short vegetation. The radius should not be less than 50 m and, if possible, kept clear of vegetation. If the search area is a square, it should be marked out by 4 corner poles. Alternating coloured poles should be used to indicate 5 m intervals on the two opposite sides of the square. In this case, surveyors should walk from one side of the square to the other, checking 2.5 m either side of the line walked. In some circumstances (ploughed field or uneven terrain) it might be necessary to reduce the checked spacing between transects or to use a trained search dog (see 4.2.2 b). If the search area is a circle then the surveyors can hold a 50 m long rope attached to the base of the wind turbine mast and walk in circles around the wind turbine, checking 2.5 m either side of the line walked. After each rotation the rope should be shortened by 5 m and another rotation made in the opposite direction. This will systematically cover the standard search area of 1 ha, but the rope method applies only on flat ground without obstacles.

If, for some reason, the entire area cannot be searched, the percentage of the searched area should be calculated for each wind turbine in order to correct the final mortality estimation.

b) Number of sampled wind turbines

If possible, every wind turbine in the wind farm should be sampled during each survey visit. In the case of larger wind farms a subsample of the turbines may be randomly selected, stratified by habitat and/or wind farm features. Classic statistical power analyses, based on the expected number of fatalities and the variation accounted in other studies (Annex 1), will yield the optimal sample size.

c) Time interval between samples

The smaller the time interval between samples the higher the number of retrieved fatalities, thus the smaller the bias from carcass removal by scavengers. For all wind farms one carcass search every 3 days (2 days interval between controls) is recommended. For oversized wind farms, the number and the choice of sampled turbines can follow an agreed random survey design. For comparison of results according to different time intervals see Arnett (2005).

d) Monitoring schedule

The entire activity cycle should be assessed. Mortality monitoring should start as soon as bats become active after hibernation and last until they get back into hibernation. Through this cycle different periods are recognized considering the different specific geographical and meteorological conditions of each region. For example, in southern Europe monitoring may start, in the vicinity of important roosts, as early as mid-February and finish as late as mid-December.

e) Search methods and recording results

The searcher should walk each transect at a slow and regular pace, looking for fatalities on both sides of the line. Bat fatalities can sometimes be found through observation of mobile insects (for example wasps and grasshoppers), which are attracted to carcasses and draw the searcher´s attention. The search should start one hour after sunrise, to minimise removal of carcasses that have appeared during the previous night by daytime scavengers and when the lighting conditions enable dead bats to be distinguished. The searcher should note the species; position of the carcass (GPS coordinates, direction relative to the wind turbine, distance to the tower, the wind turbine identification); its state (fresh, a few days old, decayed or remnants); the type of wounds; an evaluation of the date of death; and the vegetation height where the carcass was found (see below).

It is necessary to record weather conditions (air temperature, wind strength, wind direction, any storms, *etc.*) between survey visits, as these are all likely to impact on levels of bat activity at the site and therefore the number of fatalities.

A discussion of methods used to estimate bat casualties has been published by Niermann *et al.* (2007).

4.2.2 Estimation of fatalities

Mortality estimators (see 4.2.2 c) are necessary to improve estimates of the real number of bats killed at the monitored wind farms, namely by correcting for expectable sources of biases such as: removal of carcasses, searcher efficiency and percentage of area searched.

If necessary, legal authorisation should be obtained from authorities to remove, handle and transport protected species carcasses.

a) Carcass removal trials

To estimate scavenging and predation, trials must to be carried out 4 times a year in order to take into account seasonal changes in predation rates caused, among other things, by differences in vegetation height and variations in the activity of scavengers throughout the seasons.

Fox scavenging pipistrelle's carcass at night under a wind turbine in France. © Ecosphere

Bats, mice, passerines or one-day old chicks (preferably dark) can be used for these trials. As bat flesh is likely to be less attractive to carnivores than bird or mouse flesh, bats carcasses are ideal to use in carcass removal trials. If frozen, bat bodies need to be thawed before use. It is useful to mark discreetly the test-bodies to make sure that the carcasses are effectively removed from the site or eaten, instead of being only moved within the search area. This would allow carcasses to be distinguished as trial carcasses and not true fatalities. Each trial should include at least 20 carcasses and last at least 10 consecutive days (ideally daily from day 1 to 7 and then at day 14 and 21), to determine how long a carcass stays on the ground before being eaten, removed or buried by mammals, birds and insects. Combining carcass removal with search efficiency trials in an integrated trial is recommended (see below).

b) Searcher efficiency trials

• Classification of ground cover:
Searcher efficiency depends on the ground cover, because the height and type of vegetation during different seasons will affect the visibility of bat carcasses. It is therefore important to assess the detectability of dead bats in different classes of vegetation height, different percentages of vegetation cover and different habitat/physical features (such as the vegetation types, obstacles on the ground, slope, *etc.*). More details are provided in Habitat Mapping p. 26 & 28 in Arnett 2005, Arnett *et al.* 2010, Brinkmann *et al.* 2011, Limpens *et al.* 2013. These classes are important for the statistical analysis. It has to be taken into account that some estimators (*e.g.* Korner-Nievergelt 2011) need to have the ground cover classified separately in equidistant rings around the turbine.

• Trials:
The searcher efficiency should also be tested according to the different vegetation heights present in the area. In this context, trials should be repeated in different seasons in order to assess search efficiency upon different stages of ground cover development, as well as light and weather conditions. The same searchers should be kept throughout the year or, if new surveyors are required, searcher efficiency trials should be repeated.

Bat carcasses (or equivalent) should be randomly distributed at the trial plots. The coordinates of each carcass should be noted, along with the direction and distance to the mast, the type and height of vegetation around each carcass, and the identification of the nearest wind turbine.

The searcher should proceed according to the normal carcass search protocol. The overall aim is to assess the percentage of carcasses that are found by the searcher.

Some authors (*e.g.* Warren-Hicks *et al.* 2013) have been mentioning the need to combine carcass removal and search efficiency trials in an integrated trial, rather than being treated as two independent processes. Since the probability of persistence and detection are both time dependent and dependent on one another, this integration would be highly effective and desirable. In fact, integrating the carcass persistence and searcher efficiency trials can simultaneously produce time dependent carcass persistence and searcher efficiency functions for the same set of trial carcasses.

• Use of trained dogs:
A dog specially trained to search for bat carcasses can be used for mortality monitoring, but the efficiency of a dog-handler team must be tested the same way as above at each site (Arnett 2006, Paulding *et al.* 2011, Paula *et al.* 2011, Mathews *et al.* 2013). Carcass decomposition and weather conditions such as wind speed and air temperature can play important roles in dogs scenting capabilities (Paula *et al.* 2011) and should be taken into account. It is advisable that dogs and dog handlers attend organized training. If applicable, dog handlers need to obtain a licence for this purpose. The contract with the dog handler, who will always work with his dog, should specify if such training was received. Dogs can use different methods of marking such as barking and pointing. This is preferable to a dog trained to retrieve, as the bat carcass will be identified but left *in situ* for the surveyor to make notes as necessary. In difficult terrain (thick undergrowth) pointing dogs are often equipped with a beeper collar that changes its type of signal when the dog is pointing. Dogs are already being used to increase the efficiency of the search in some countries in Europe such as: Portugal, United Kingdom, Spain and Germany.

Surveyor in the UK setting out on search with dog: flags for marking the locations of dead bats. © F. Mathews

c) Mortality estimators

Different algorithms have been developed to estimate bat mortality. Most of them were based on Winkelman's formula (1989), designed for birds, although this formula has also been used in France for bats (André 2005, Dulac 2008). Since then, different estimators have been developed for bats, namely in the United States (Erickson 2000, Huso 2010), United Kingdom (Jones 2009), Germany/Netherlands (Brinkmann *et al.* 2011, Limpens *et al.* 2013), Switzerland (Korner-Nievergelt *et al.* 2011) and Portugal (Bastos *et al.* 2013). Most of them now include a correction factor for the percentage of area effectively surveyed.

It is advisable to test a variety of different methods as results can vary considerably. For example, Winkelman's formula has a tendency to overestimate bat mortality, even when the correcting factor for percentage of the area effectively surveyed is added.

Usually, the estimation of bat mortality (real number of bats killed at a wind farm) is calculated using the carcasses found on the search plot of each turbine multiplied by correction factors that take into consideration the probability of a carcass to persist in the search plot (carcasses persistence), the probability of a carcass to be found by an observer (searcher efficiency), and/or the probability of a carcass to be within the searchable area (search area).

Some estimators didn´t take into consideration the irregular distribution of the carcasses in the searched area, although a large percentage of these is likely to be found within 30 meters from the tower (Cornut & Vincent 2010a, 2010b, Rico & Lagrange 2011, Sané 2012, Beucher & Kelm 2013). Furthermore, until very recently, if no bats were found under the turbines then it was not possible to estimate the number of bat fatalities for this specific site, and additionally no confidence intervals could be assumed together with an estimation (see below).

Bernardino *et al.* (2013) compared seven widely used estimators and highlighted their assumptions and limitations. The conclusion was that a universal estimator that would produce unbiased estimates under any study design or circumstances is still not available. The authors identified factors that can improve the quality of the estimates, such as (1) shorter search intervals consistently applied throughout the year, (2) larger search areas, and (3) higher searcher efficiencies.

In order to improve its effectiveness, some new estimators take some of these disadvantages into consideration:

• Huso (2010) developed an estimator that takes into account the partial coverage of the area beneath the turbines and assumes that carcasses persistence times have exponential distributions. This features a constant "hazard rate" implying that carcasses remain equally attractive to scavengers over time.

• A German estimator was developed in a national research project financed by the BMUB (Ministry of Environment, Nature Conservation, Building and Nuclear Security (Niermann *et al.* 2011, Korner-Nievergelt *et al.* 2011)). In contrast to Huso's estimator this estimator assumes that a confidence interval cannot be lower than the number of dead bats actually found under the wind turbines. Niermann's webpage shows how to calculate the mortality according to Korner-Nievergelt 2011 (http://www.kollisionsopfersuche.uni-hannover.de/, only in German). One important advantage of this approach is that the formula can be adapted to different distributions of searcher efficiency or carcass removal rates.

• Péron *et al.* (2013) used superpopulation capture-and-recapture models (used for population sizes). This approach integrates time and age variation in the parameters and accounts for possible extended carcass persistence with influence in the detection process between search intervals.

• Bastos *et al.* (2013) produced stochastic dynamic simulations that consider the non-constancy and inter-dependency of the commonly used parameters, such as search efficiency and carcass persistence, for bias-corrected estimates. This framework can provide algorithms capable of estimating potential real mortality even in the absence of detected carcasses. This approach is proposed as an innovative starting point in preventing the wrong interpretations of the false zeros meaning by the decision-makers.

• The model of Korner-Nievergelt *et al.* (2013) also allows estimation of fatalities on the basis of extrapolation of sampled data (for example for nights within the search interval). In difference to other approaches, these authors developed a model that allows skipping the carcass search process, calculating real fatalities only on the basis of wind speed and bat activity. In this context, the study design has to be the same as the study design proposed by the authors in terms of turbine type, rotor diameter, species composition, activity patterns, wind conditions, bat detector types, recording sensitivity and geographical region.

• The Portuguese Wildlife Fatality Estimator (www.wildlifefatalityestimator.com) was created by Bio3 in partnership with Regina Bispo and aims to help users to properly apply methodologies and save time in the data analysis (Bispo *et al.* 2010). The Wildlife Fatality Estimator is a free online platform that can be used to estimate bat mortality associated with wind farms or other human-made infrastructure, using three commonly used estimators: Jain *et al.* 2007, Huso 2010 and Korner-Nievergelt *et al.* 2011. The platform includes 3 application modules: "Carcass Persistence", "Search Efficiency" and "Fatality Estimation".

d) Cumulative effects

As many years often elapse between the pre-construction survey and the post-construction monitoring, other wind farms may have been constructed in the vicinity by the time monitoring starts at the site in question. Therefore a new evaluation of the cumulative effects assessed for the ***EIA*** should be carried out at the end of the monitoring period, in order to refine the previous estimation of impacts on bat populations and help to determine appropriate mitigation measures to reduce mortality.

5 Avoidance, mitigation and compensation

Larger wind turbine developments can have significant impacts on bats (see Chapter 2). Impact assessments (including formal ***EIA***) should determine the potential impacts of a particular project on bats and their habitats pre-, during and post-construction and what their level of significance is. Since bats are protected by international and national legislation in all European countries, if significant adverse impacts are expected, impact assessments should also provide effective measures to avoid and then to mitigate (if ***avoidance*** is not possible) these impacts and, finally, to compensate for any residual effects. This will also be necessary if any unpredicted significant adverse impacts are detected during post-construction monitoring. The effectiveness of the implemented ***avoidance***, ***mitigation*** and ***compensation*** measures should also be monitored and changes applied as necessary.

Appropriate measures for ***avoidance***, ***mitigation*** and ***compensation*** for any wind turbine development can only be designed using knowledge about bat species presence and activity gleaned from surveys carried out as part of an impact assessment. Such measures will also be determined by the characteristics of the individual wind turbine development. Thus, these measures will always have to be site-specific and are very often species-specific. Furthermore, expert knowledge regarding the ecology of different bat species is essential to develop adequate measures.

Avoidance, ***mitigation*** and ***compensation*** measures will be discussed here according to the relevant impacts on bats they are designed to address.

Potential options for ***mitigation*** of ***small wind turbines*** include stopping SWTs from running during darkness hours, increasing the ***cut-in wind speed*** and preventing turbine rotation at low wind speeds. Although in some situations a form of ***mitigation*** may be required (*e.g.* when collision mortality has occurred), there is no evidence yet that either of the above ***mitigation*** options are practical and/or effective for SWTs. We therefore stress that until more data become available, appropriate and careful siting decisions are crucial. SWTs should be sited at least 25 m away from habitats commonly associated with higher levels of bat activity, including:

a. Large hedgerows or treelines
b. Broadleaved or coniferous woodlands or woodland edges
c. Single mature trees, particularly when suitable for roosts
d. Watercourses, ponds or lakeshores
e. Buildings (occupied or derelict, including bridges and mines) where suitable for roosts. Where proposed development is on or near to buildings any construction work inside or near roof spaces should include checks for the presence of roosts (*e.g.* see Hundt *et al.* 2012).

These guidelines do not relate to micro-turbines that are installed on boats. However, if a boat during the night is within 20 m of (mature) hedgerows or tree lines, broadleaved or coniferous woodlands or woodland edges, single mature trees (particularly when suitable for roosts), watercourses, ponds or lakeshores, or buildings, we recommend that the turbine should be turned off.

5.1 Fatalities

The most significant impact of operating wind turbines on bats is direct killing (Arnett *et al.* 2013a), caused due to collision and/or barotrauma (Arnett *et al.* 2008, Baerwald *et al.* 2008, Grodsky *et al.* 2011, Rollins *et al.* 2012). Migrating bats and bats from local sedentary populations are often killed by wind turbines (Brinkmann *et al.* 2011, Voigt *et al.* 2012), sometimes in large numbers (Hayes 2013, Arnett *et al.* 2013a).

However, bats may also be killed during construction of wind turbines and ***supporting infrastructure***, for example in roosts (hibernating individuals and bats in maternity roosts are particularly vulnerable).

Since reliable data on population sizes on European level are still not available for most bat species, the impacts of mortality caused by wind turbines (or by any other cause) on bat populations are not known. However, it is evident that, due to their extremely low reproductive output (Barclay & Harder 2003), any increase in mortality rate could be critical. Also, since fatalities of bats from long-distance migratory populations regularly occur (Voigt *et al.* 2012, Brinkmann *et al.* 2011), it is evident that wind turbines affect bat populations over significant geographical distances. Furthermore, there was 121.5 GW of installed wind power capacity in Europe at the end of 2013 with an expected annual growth rate over 10% (Corbetta & Miloradovic 2014), so cumulative effects and a cumulative increase in bat mortality have to be considered.

Since all European bats are protected by international and national legislation, any intentional killing is forbidden by law. Therefore, avoidance, or at least reduction to a minimum, of bat mortality by wind turbines, is not only a priority for bat conservation, but also a legal obligation in Europe. Setting any general thresholds for bat mortality and/or wind speed that would trigger mitigation of bat fatalities is not only considered arbitrary, ineffective, inadequate and unsustainable (Arnett *et al.* 2013a, see also Chapter 3), but in Europe also questionable from a legal perspective.

Based on this, effective measures to avoid and to mitigate bat fatalities have to be designed for every wind turbine development on case-by-case basis through the appropriate impact assessment process. As stated above, the sequence of measures should be ***avoidance*** of fatalities first and then ***mitigation*** (if complete ***avoidance*** is not possible), while the possibility to compensate for fatalities is, at best, questionable (see 5.1.3).

Noctules (N. noctula) are the species most affected by wind turbines in Germany (here at Puschwitz in Saxony). Migrating as well as local populations of different bat species are found throughout Europe as casualties under wind turbines. © M. Lein

A Schreiber's bent-winged bat (Miniopterus schreibersii) severed from the head to the hips by a rotor blade (Camargue wetlands 2006). © E. Cosson

5.1.1 Avoidance

5.1.1.1 Planning of site layout

The best strategy to avoid bat fatalities, to benefit both bat conservation and in economic terms, is preventive planning. This is where bat activity is taken into consideration during the ***screening*** and ***scoping*** phases of a wind farm development project. Even at a strategic planning level, where authorities identify sites that may be appropriate for wind farm development, possible impacts on bats should be considered.

Due to the high risk of fatalities (Arnett 2005, Behr & von Helversen 2005, 2006, Rydell *et al.* 2010b, Brinkmann *et al.* 2011) wind turbines should not be installed within broadleaved or coniferous woodlands or within 200 m of woodlands (see also 2.1).

The most effective avoidance of fatalities, at least for some species, can be achieved by careful planning of the site layout. In general, the highest mortality is expected in areas of greatest bat activity such as ***migration*** and ***commuting*** routes, important foraging areas, and close to bat roosts, particularly for species and populations that are at higher risk due to their specific ecology (see Table 3). Appropriate impact assessment will gather sufficient information on spatial and temporal patterns of bat activity and on bat roosts on the proposed development site, especially in the areas of the proposed wind turbine sitings, which will enable reliable decision-making on site layout.

Where wind turbines are proposed in areas of high bat activity or close to roosts, they should be re-sited away from these areas. If re-siting of these wind turbines is not possible, individual wind turbine locations should be abandoned accordingly. If high bat activity is recorded throughout the development site, abandonment of the project should be considered, to avoid the necessity for complex ***mitigation*** schemes that may be unsuccessful.

5.1.1.2 Prevention of roost sites destruction while bats are present within them

Destruction of bat roosts is prohibited by law in the EU and many other European countries and must be avoided. Even if bat roosts are not legally protected, their destruction should still be avoided.

Precautionary measures (following the ***precautionary principle***) include avoiding demolition work or felling particularly during sensitive periods such as the maternity and hibernation seasons, or whenever the bats are present, checking the roosts prior to destruction and having a bat specialist monitoring the demolition, in order to take any emergency measures that might be necessary to prevent fatalities. In the EU and many other countries this can only occur under a licence and bats must not be harmed.

Appropriate impact assessment will gather information on bat roosts at the proposed development site (see 5.2), and appropriate periods for any construction works (and any other activities that may affect bats) will be best determined by impact assessment on a case-by-case basis.

5.1.1.3 Elimination of attraction factors

During construction and operation of a wind farm, all known factors that can lead to bats being attracted to the site and to the wind turbines must be eliminated.

Bats roosting in nacelles have been reported in Europe in both onshore (Hensen 2004) and offshore (Ahlén et al. 2009) wind turbines. Although roosting in the nacelle itself does not seem to cause significant fatalities (Dürr & Bach 2004), searching for roosts in wind turbines and emergence/re-entry from/into such roosts and ***swarming*** at the entrance can lead to fatalities. Therefore, all wind turbines, particularly the nacelles, should be designed, constructed and maintained in such a manner that they do not support roosting bats – all the gaps and interstices should be made inaccessible to bats.

Areas around wind turbines disturbed by their construction may provide conditions favorable for aerial insects upon which most bats feed (Grindal & Brigham 1998, Hensen 2004). Insects are attracted to lights (security lights at the bottom of tower (Beucher *et al.* 2013)) and by the heat produced by some nacelle types (Ahlén 2002, Hensen 2004, Horn *et al.* 2008, Rydell *et al.* 2010b). Concentrations of insects in the areas around wind turbines thus entice bats to forage in these areas, which can lead to fatalities (Kunz *et al.* 2007, Horn *et al.* 2008, Rydell *et al.* 2010b). The colour of wind turbines (Long *et al.* 2011) and some acoustic effects (Kunz *et al.* 2007) are also suspected to attract flying insects and bats into the risk zone. Therefore, wind turbines and their immediate surroundings should be managed and maintained in such a manner that they do not attract insects (*i.e.* the concentration of insects in the wind turbine vicinity should be reduced as much as possible, but not such that insect abundance is affected elsewhere on the site). Some of the measures that can accomplish this and that should be implemented at all wind farms are:

- using lighting that does not attract insects,
- using lighting only when needed, except where it is mandatory for safety reasons,
- preventing the retention of water and the growth of weeds and new shrub growth in the immediate area of wind turbine construction (wind turbine operation zones, access roads, *etc.*),
- new hedges, other lines of shrubs and trees, and forests or orchards should not be allowed to become established in the 200 m buffer zone around turbines and such structures should not be used as ***compensation*** measures within the given distance.

5.1.2 Mitigation

5.1.2.1 Blade feathering and increase of cut-in wind speeds

Blade feathering and increase of ***cut-in wind speeds*** are currently the only proven ways to reduce bat fatalities at operating wind farms (Arnett *et al.* 2013a). Very extensive studies in North America (Baerwald & Barclay 2009, Arnett *et al.* 2011, 2013c) and Europe (Behr & von Helversen 2006, Bach & Niermann 2013) proved that small increases of turbine ***cut-in wind speed*** and ***feathering*** of blades resulted in significant reductions in bat fatalities (by 50% or more).

It's important to note that some models of wind turbines (usually older ones) will continue to rotate freely at speeds that can still cause bat fatalities when ***cut-in wind speed*** is increased. In such cases, blade ***feathering*** or other methods that would prevent freewheeling (or reduce rotation speed to minimum) at wind speeds below cut-in speed must also be implemented to prevent/minimise bat fatalities.

Bat activity is significantly correlated with wind speed and other meteorological variables such as air temperature, relative humidity, rain and fog (Horn *et al.* 2008, Bach & Bach 2009, Behr *et al.* 2011, Brinkmann *et al.* 2011, Amorim *et al.* 2012, Limpens *et al.* 2013). A substantial proportion of the bat fatalities at operating wind farms occurs during relatively low wind speeds (Arnett *et al.* 2008) and high temperatures (Amorim *et al.* 2012). This explains why an increase of the ***cut-in wind speed*** and/or ***feathering*** of blades during low wind speed conditions reduces bat mortality.

However, bat activity and wind tolerance may differ significantly at one site between years (Bach & Niermann 2011, 2013, Limpens *et al.* 2013) and even more between sites (Seiche *et al.* 2007, Arnett *et al.* 2008, Rydell *et al.* 2010a, Arnett *et al.* 2011, 2013c, Limpens *et al.* 2013), regions and countries (Dürr 2007, Rydell *et al.* 2010a, Dubourg-Savage *et al.* 2011, Niermann *et al.* 2011, Georgiakakis *et al.* 2012, Limpens *et al.* 2013) and especially between species (Dürr 2007, Seiche *et al.* 2007, Rydell *et al.* 2010a, Bach & Niermann 2011, Dubourg-Savage *et al.* 2011, Niermann *et al.* 2011).

Therefore, reliable and effective thresholds for ***cut-in wind speed*** and temperature (or algorithms based on these and other weather variables, spatial and temporal patterns of bat activity and species present) should only be determined on a case-by-case basis, following the results obtained during the impact assessment (see also Chapter 3). It would be inappropriate to set national or European standards.

Power loss and the economic cost of blade ***feathering*** and increase of ***cut-in wind speeds*** are inevitable in most cases, but studies have shown these to be negligible, *e.g.* <1% of total annual output (Brinkmann *et al.* 2011, Arnett *et al.* 2013c). Finely tuning pre-construction rough cut-in speed and temperature thresholds into refined post-construction site- and species-specific multifactorial models very efficiently reduces excessive production losses and bat fatalities at the same time (Lagrange *et al.* 2011, 2013).

In Portugal, this 7-turbine wind farm has one located 158 m from an important hibernating roost (around 4000 Miniopterus schreibersii and 150 Rhinolophus ferrumequinum). The cut-in speed of that turbine is increased to 5 m/s in October, November, December, March and April. © J. Rydell

Multifactorially modeled blade ***feathering*** and increase of ***cut-in wind speeds*** offers an ecologically sound and economically feasible strategy for reducing bat fatalities at wind energy facilities and should be implemented broadly.

However, any model should be developed and implemented very carefully, especially those based on bat activity at nacelle height to statistically predict fatalities, because of very large standard deviation of such predictions (Brinkmann *et al.* 2011, Limpens *et al.* 2013). Models based on site-specific levels for wind and temperature, *e.g.* below 7.5 m/s or above 12°C (Bach & Niermann 2011, 2013), and/or other environmental conditions (*e.g.* Lagrange *et al.* 2013), allow to eliminate bat fatalities due to their flight activity at nacelle height. Authorities should therefore support this opportunity, determined on case-by-case basis.

Where wind farms development is still permitted in forests, blade ***feathering*** or increasing ***cut-in wind speeds*** should be obligatory, due to the exacerbated risks that this type of siting implies for all bats (see 2.1).

The permit delivered for these 5 wind turbines (Perwez, Wallonia, Belgium) includes blade feathering because migrating bat species had been detected during the EIA. © T. Kervyn

CASE STUDY 1 - Belgium

In southern Belgium (Wallonia), when sensitive bat species are detected during the ***EIA***, blade ***feathering*** is implemented below 6 m/s (measured at nacelle height) for a period of six hours from sunset, between the 1st of April and the 30th of October when air temperature is higher than 8°C (or 10°C in lowlands) in the absence of rain.

During autumn ***migration***, between the 1st of August and the 15th of October, blade ***feathering*** is also implemented between sunset and sunrise when wind speed is below 7 m/s (measured at nacelle height), and air temperature higher than 5°C (or 8°C in lowlands).

Electricity production is theoretically reduced by 2% in southern Belgium (Wallonia) using these thresholds.

Source: Thierry Kervyn (Belgium)

CASE STUDY 2 - Germany

Turbine-specific curtailment algorithms based on multifactorial models – an approach from Germany

In the years 2007 and 2008 the collision risk of bats at wind turbines was investigated in a large-scale study funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety at 70 wind turbines at 35 sites in different geographical regions all over Germany (Brinkmann *et al.* 2011). Bat activity was measured by acoustic surveys at the nacelle of the turbines. Additionally, daily fatality searches were carried out at 30 of the turbines. This large data set allowed for a detailed analysis of the parameters correlated to a high bat activity at the nacelle and, hence, a high collision risk. Based on this data-set two models were developed to predict

a) the level of bat activity at the nacelle - from time of year, time of night and wind speed
b) the expected number of fatalities - from the acoustic bat activity measured at the nacelle.

These two models were combined in subsequent years to determine, without current measures of the bat activity, the collision risk at a certain time using the parameters: time of year, time of night and wind speed alone. A curtailment algorithm to stop the turbines at times of high predicted collision risk and low energy production was developed. The effectiveness of this 'bat-friendly' curtailment algorithm has already been demonstrated at 18 turbines in a subsequent research project in the year 2012.

This method is recommended as standard mitigation method in guidelines of several German federal states and is already being applied in some current projects.

The planning process during post-construction monitoring usually comprises the following steps:

a) Survey of bat activity at the nacelle in the first year of turbine operation: The aim of this survey is to determine the level of bat activity at the specific turbine and to detect possible differences from the activity patterns assumed by the model (*e.g.* regional differences regarding the seasonal activity). To avoid high collision risks in the first year, the turbine is operated with simple curtailment rules based on a pre-construction study.
b) Development of a site-specific curtailment algorithm: The software tool ProBat calculates curtailment algorithms based on the results of the acoustic survey and on wind data (http://www.windbat.techfak.fau.de/tools/, currently available only in German).
c) Survey of bat activity at the nacelle during the second year of operation: This second survey should detect differences between years. During the second year, the turbine is already operated with the specific algorithm based on the results of the first year.
d) Adjustment of the algorithm according to the results of the second year: ProBat can be used to calculate algorithms based on the averaged results of the two years of survey.
e) Operation of the turbine with the turbine specific-curtailment algorithms from the third year on. Acoustic activity surveys are not intended anymore. Another survey may be useful to check the algorithm after several years.

Currently, algorithms are being improved. For example, specific models for different regions in Germany are being developed to include regional characteristics, *e.g.* seasonal activity peaks due to bat migration.

Source: Johanna Hurst, Oliver Behr & Robert Brinkmann.

5.1.2.2 Deterrents

Acoustic (Szewczak & Arnett 2008, Arnett *et al.* 2008, Arnett *et al.* 2013b), visual (light) and electromagnetic (Nicholls & Racey 2009) deterrents have not yet been proven to be effective at preventing bats from approaching wind farms, let alone to reduce bat fatalities at operating wind farms. Also, the impact of such measures on the public and on other wildlife, like birds or insects, has not been assessed to date (Amorim *et al.* 2012). Therefore, although research into deterrents may have potential, they still cannot be considered as a practical ***mitigation*** strategy to avoid bat fatalities.

5.1.3 Compensation

In contrast to impacts on habitat, where loss of habitat on site may be compensated by protection or restoration of habitat off site, it is not possible to compensate for fatalities. Since population level impacts of bat mortality caused by wind turbines are still unknown, the development of well-based, adequate and measurable ***compensation*** schemes is not possible at the population level. This particularly concerns long-distance migratory populations, because it would require improving their birth and survival rates hundreds of kilometres away from the development site (at often unknown roost sites) at a large scale and before the operational phase of a wind farm (Voigt *et al.* 2012). All of these are strong arguments that fatalities have to be avoided or mitigated as much as possible.

However, since some fatalities may still occur even after all known options for ***avoidance*** and ***mitigation*** are exhausted, measures regarding the protection and improvement of habitats should be implemented, in order to increase adult and juvenile survival rates of the impacted populations of resident species.

5.2 Loss/Deterioration of Habitats

Construction of wind turbines and ***supporting infrastructure*** may destroy or damage bat roost sites, flight paths and feeding areas. This is especially the case when extensive changes in the landscape and habitats are proposed, such as when wind farms are constructed within forests (see 2.1). Nevertheless, high activity of foraging and ***commuting*** bats has been recorded at operating wind farms elsewhere (*e.g.* Brinkmann *et al.* 2011, Amorim *et al.* 2012). Loss of roost sites, especially in areas where roosts are scarce, is likely to have a greater impact than changes in habitat due to wind turbine construction (*e.g.* Brinkmann *et al.* 2011, Amorim *et al.* 2012). However, even a small decrease in the foraging potential of the landscape (*e.g.* as a result of the use of deterrents – see 5.1.2.2) may have long-term effects such as a decrease in the survival and reproductive capacity of individuals and hence the maintenance of populations, particularly migratory ones. The destruction of roost sites when bats are present (and the resulting fatalities) is not only illegal, but it is also impossible to adequately mitigate or compensate for, and must be avoided (see 5.1.1.2).

Construction of wind farms (including ***supporting infrastructure***) may also increase the foraging potential of the habitat for bats (*e.g.* an increase in clearings and inner edges within forests and the resulting attraction of aerial insects in otherwise less structured landscapes) could lead to an increase in bat activity and, thus, risk of fatalities.

If significant impacts on bat roosts, foraging area and ***commuting*** paths are expected, ***avoidance***, ***mitigation*** or ***compensation*** schemes should be designed to cancel them. If any of these measures conflict with measures for ***avoidance/mitigation*** of fatalities, prevention of fatalities must always take precedence.

5.2.1 Avoidance

The best strategy for avoiding bat habitat loss/deterioration, both in terms of bat protection and from the economic point of view, is preventive planning. Wind farms should, whenever possible, be planned away from existing or potentially (*e.g.* recently planted forests) important bat habitats, as determined by impact assessment.

Re-siting of individual turbines and ***supporting infrastructure*** and abandonment of individual turbine locations should be considered (more details in 5.1.1.1), as well as abandonment of the whole project if habitats at the development site are particularly important for bat conservation.

Wind turbines should not, as a rule, be installed within all types of woodland or within 200 m due to the exacerbated risks that this type of siting implies for all bats (see 2.1).

5.2.2 Mitigation

Construction of wind turbines and ***supporting infrastructure*** should be planned and carried out in such a way that important bat habitats are disturbed as little as possible. Natural habitats such as broadleaved or coniferous woodlands, wetlands and grasslands, even as small patches in expansive agricultural landscapes, and landscape features such as hedgerow networks, individual trees, water bodies or water courses increase the likelihood that bats may roost, forage and/or commute in these areas. Therefore, disturbance of these habitats should be avoided.

A wind farm in the Camargue delta (southern France). 21 wind turbines were built on an embankment in 2005. In 2006, 12 dead bats were found, among them Schreiber's bent-winged bats (M. schreibersii). The building permit was granted at a time when no bat survey was needed for an impact assessment, although this wetland area (Ramsar site) is a hot spot for wintering birds and migrating and foraging bats. © E. Cosson

5.2.3 Compensation

Compared to ***avoidance*** and ***mitigation***, compensation is less efficient, both in terms of bat conservation and 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 impacts cannot be avoided or mitigated, *e.g.* inevitable loss of tree roosting potential when wind farms are constructed within forests.

When it is necessary, ***compensation*** should be informed by the impact assessment and should be species-specific, adequate, at least proportional to loss, timely, permanent and should not destroy other natural features. Possible means of ***compensation*** are protection, improvement and/or restoration of affected habitats and their functional elements, especially around roosts, foraging areas and flight paths. When ***infrastructure*** associated with wind farms is constructed within woodlands, it is necessary to compensate for lost roosts by appropriate management of nearby woodlands, especially through protection of old, decaying trees.

The efficacy of purpose-built artificial roosts such as bat boxes requires further research. Therefore these cannot be relied upon as sufficient ***compensation*** for destroyed roosts. However, some studies suggest that bat boxes can be effective for certain species in certain habitats and regions (Ciechanowski 2005, Baranauskas 2010).

Generally, ***compensation*** measures should be implemented outside of the development site, but within the range of the affected local population.

5.3 Disturbance

Although possible sources of disturbance and their effects on bats and their populations are still not completely understood, it is evident that bats may be disturbed by human activities and especially by major development. Disturbance can impact bats at the population level (Natural England 2007). All bats are protected from any deliberate disturbance by international legislation in the EU and many other European countries, and such protection should be implemented in the others.

The high activity of foraging and ***commuting*** bats at operating wind farms that often occurs (*e.g.* Brinkmann *et al.* 2011, Amorim *et al.* 2012, Bach *et al.* 2013b), as well as the numbers of bat fatalities suggests that large wind turbine operation does not deter bats through disturbance. However, turmoil, vibrations, noise and the use of lighting during construction may disturb bat foraging and ***commuting*** activity (*e.g.* Schaub *et al.* 2008, Stone *et al.* 2009), roosting (*e.g.* Parsons *et al.* 2003) and hibernation (*e.g.* Daan 1980, Thomas 1995), when they are the most vulnerable to disturbance (Natural England 2007). All bat species are sensitive to disturbance in roosts, but while foraging and ***commuting*** they are not equally susceptible to different disturbance sources and even levels (*e.g.* Fure 2006).

Annual and daily life cycle of bats varies across Europe and it also differs between species (see 2.2 and 3.2.1).

Based on this, an impact ***assessment*** should determine if construction activities will disturb bats in their roosts (particularly during the maternity and hibernation seasons) or whilst foraging and ***commuting*** is expected. If significant impacts of disturbance on bat roosts, foraging and ***commuting*** are expected, measures should be developed and applied to avoid and to mitigate. ***Compensation*** is not considered to be possible.

5.3.1 Avoidance

The best strategy to avoid disturbance of bats is careful planning of the construction timetable:

- Disturbance of occupied roosts, particularly hibernacula and nurseries where fatalities may result (see also 5.1.1.2), should be prevented by restricting construction activities in their vicinity.
- Disturbance to foraging and ***commuting*** should be prevented by restricting some construction activities during times of the day and year when bats are active (*i.e.* construction should generally be planned for the daytime).

Appropriate impact assessment will gather sufficient information on temporal patterns of bat activity and on bat roosts at the proposed development site to facilitate the design of an appropriate construction timetable that minimizes impacts.

5.3.2 Mitigation

When ***supporting infrastructure*** for the wind farm has to be constructed within a forest, disturbance may be inevitable. Disturbance of nursing and hibernating bats should still be avoided and therefore construction should not be proposed during the maternity and hibernation seasons if roosts are present. Where significant ***infrastructure*** construction is proposed it may be appropriate to phase this so that disturbance does not occur across the whole site at the same time. In all cases, lighting should not be used unless it is mandatory for safety reasons.

6 Research priorities

During the last years several studies have been carried out on bats and wind turbines (*e.g.* Baerwald *et al.* 2008, Rydell *et al.* 2010b, Bernardino *et al.* 2011, Brinkmann *et al.* 2011, Ferri *et al.* 2011, Amorim *et al.* 2012, Camina 2012, Georgiakakis *et al.* 2012, Beucher *et al.* 2013, Lagrange *et al.* 2013, Santos *et al.* 2013). Investigations to date have concentrated on the influence that wind farms may have on individual bats through collision and barotrauma and how to mitigate these effects whilst enabling wind farms to generate sufficient economic returns.

However, our knowledge of the impact of wind turbines and wind farms on the environment and particularly bats is still limited and there is a need for further research. Further research projects are needed to increase our understanding on the impact of wind farms on bats either at a population level or in different landscapes.

Compared to birds, the general knowledge about bat biology is rather selective. In particular, insufficient is known about bat ***migration*** throughout Europe. This information is key to evaluating the risks of proposed wind farm projects. Furthermore, research projects should assess the risk of existing wind farms for individual bats but, more importantly, assess the impact of these fatalities on bat populations. There is still an urgent need to find different solutions that will minimise impacts for future wind farm construction.

The following questions outline areas where research is needed:

1. Why do bats collide with turbines?
2. What are the best methods to assess likely impacts on bats from wind turbine construction during impact assessments and post-construction monitoring (methodology development)?
3. How effective are the ***mitigation*** measures (mainly change of ***cut-in wind speed*** and ***feathering***) that are used today (% reduction of collisions)?
4. How large is the effect on populations, particularly of migrating species?
5. What is the cumulative impact of wind farm development?
6. What mortality rate would negatively affect the population of a given species?
7. In which habitats/landscapes wind turbines should not be allowed due to high collision rate?
8. What is the behaviour of bats migrating over large water bodies, especially seas, what is their number?
9. Are there any negative effects from ***small wind turbines*** on bats?

The following sections (6.1 to 6.7) outline the research needs (*priorities are marked in italics*) and suggest possible investigation methods.

6.1 Why do bats collide with turbines?

In Europe, during the last years, many projects have included post-construction monitoring of bat mortality at wind farm sites. The aim of this work was to collect data that enabled the development of a cut-off algorithm, depending on activity, season, wind speed and temperature. An understanding of why bats move around and/or hunt around wind turbines is, however, essential for understanding the mechanisms behind turbine mortality and might also lead to new ***mitigation*** measures.

The reasons that bats collide with rotor blades are still unclear. A series of laboratory studies by Long *et al.* (2010a, b) showed that ultrasonic echoes returned from moving SWT blades were imperfect, potentially increasing collision risk by lowering detection of moving blades. This may be why bats avoid SWTs. Horn *et al.* (2008) and Cryan *et al.* (2014) suggested that bats may be attracted towards turbines, but we do not know the underlying mechanisms behind these observations. We also do not know if bats can detect and therefore react to fast moving turbine blades.

The following aspects have to be studied for a better understanding of the problem:
- Hunting behaviour of bats,
- Insect density around wind turbines,
- Perception of wind turbine blades.

Research questions	**Possible methods**
• Are bats hunting around the nacelle because of high insect densities? Are insect densities around turbines high in comparison to the wider landscape and, if so, why? Where do the insects come from (attraction from wider surroundings, wasteland from the ground area around the mast)? Is it possible to influence the insect density around the nacelle?	• Insect radar (see Chapmann *et al.* 2011), • Insect traps.
• Why do bats collide with turbines? Arnett (2005) describes ***avoidance*** behaviour of several bats in front of the blades, while others did not show any ***avoidance*** behaviour. How do bats perceive the rotating blades with their echolocation system? Can they assess the speed? This knowledge could be used to find ways of making blades more noticeable to bats.	• Radio tracking, • Behavioural studies with detectors and thermal imaging cameras, • Laboratory experiments, • Echolocation experiments with an artificial bat (see Long *et al.* 2010a,b), • Physiological and behavioural studies.
• Are high flying bats attracted to wind turbines?	• Thermal imaging camera, • Automatic bat activity registration systems, • At ground level and high altitude.
• Generic studies are needed on the behavioural responses of different species to construction, operational and removal phases of wind farms, based on life history traits, population dynamics, ecology and abundance. This will establish species-specific sensitivities to several types of large-scale wind farms and identify the influence of turbine lighting on bat behaviour.	• Radio tracking, • Behavioural studies with detectors and thermal imaging cameras.

6.2 What are the best methods to assess likely impacts on bats from wind turbine construction during impact assessments and post-construction monitoring (Methodology development)?

Methods need to be developed or adapted to be able to study:

- Bats at high altitudes,
- Species distributions on a broad level (pre-survey phase),
- New methods for acoustic monitoring at nacelle height, due to longer rotor blades,
- Wind farms in forests.

Research questions	Possible methods
• *Quantifying collision rates of different bat species in different habitats / regions should be given a high priority. Systematic and standardised studies are needed of bat mortality at large scale wind farms which are located in different risk zones,* i.e. *on* ***migration*** *routes but also in forests and areas with high hedgerow densities.*	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Grünkorn *et al.* 2005, Niermann *et al.* 2011).
For post-construction monitoring: • Studies on how large the search area for bat fatalities has to be to be able to make robust estimates? • Studies on possible species-specific removal rate of bats.	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Niermann *et al.* 2007, 2011).
• Establish adequate census methods for bat activity at different altitudes.	• Thermal imaging camera, • Detector/multi microphone arrays, • Bat activity registration systems, • At ground level and high altitude.
• Establish adequate census methods for bat activity above forests.	• Detector/multi microphone arrays, • Masts for appropriate height, • Bat activity registration systems.
• Develop and test models of geographical and ecologically relevant species distribution maps. These highlight the most important foraging areas across a large geographical range; results would be displayed along a gradient from most important foraging area to least important (*e.g.* Jaberg & Guisan 2001, Santos *et al.* 2013).	• GIS and habitat suitability models, (*e.g.* Ecological Niche Factor Analysis).

6.3 How effective are the mitigation measures that are used today?

Further information is needed on the following questions:

- Is it acceptable to use the same ***cut-in wind speed*** in different wind farms or does it need to be site and/or season specific?
- Wind turbines are designed to be operational for more than 20 years. Do changes in bat activity resulting from landscape or climatic change make it necessary to correct/update ***mitigation*** measures after a number of years?

Research questions	Methods
• *Is it important to determine site specific* ***cut-in speed*** *algorithms?* • *Is it important to repeat post-construction monitoring after 10-15 years?*	• Acoustic monitoring at nacelle height in combination with systematic collision mortality studies (methods after Arnett 2005, Grünkorn *et al.* 2005, Niermann *et al.* 2007, Brinkmann *et al.* 2011).

6.4 How large is the effect on populations, especially the cumulative effect of wind farms?

Further information is needed on:

- Which populations are involved (local or migrating bats),
- Whether mortality affects bats at the population level.

Research questions	Methods
• *Potential population level impacts of bat collision mortality (which are completely unknown).*[3]	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Grünkorn *et al.* 2005, Niermann *et al.* 2011), • Genetic studies, • Population studies, • Population models.
• Recent studies from Germany (Voigt *et al.* 2012) indicate that not only migrating bats, but also foraging bats from the local populations collide with turbines. How large is the percentage of migrating bats in relation to residential bats that are involved in bat fatalities at wind farms?	• Genetic studies and isotope analysis from systematic collision studies;

[3] The effects on the population level are unknown not only in regard to bat collision mortality as a result from wind farms, but also regarding mortality through bat collision with traffic or regarding reduced reproduction caused by disturbance of roosts, *etc.* resulting from other types of development (there are a few study cases of mortality induced by traffic for which it has been shown that those may be unsustainable for populations in the long term (*e.g.* Altringham 2008)). This kind of research should be set up in a broader sense.

• Currently, many wind farms are in operation without adequate ***mitigation*** measures (such as increased ***cut-in speed***) in place. How large is the ***cumulative effect*** of single wind turbines and wind farms on a local, regional, national and international level?	• Genetic studies, • Isotope studies, • Population studies, • Population models.
• Long-term studies are required to determine long-term effects of wind farms. Such effects could, for example, include habituation of bats to wind farms, which could cause the impact to decrease over time. For migratory bats such phenomena are not expected but this could be possible for local bats. Significant impacts on the population only become apparent in the long-term.	• Ringing, • Population studies, • Isotope studies.

6.5 In which habitats/landscapes wind turbines should not be allowed due to high collision rate?

Further information is needed on:

- Important foraging sites,
- Regional specific collision rates/problematic species,
- Where in space and when in time / season ***migration*** takes place,
- Whether flyways/***migration*** zones exist and if so, whether these are recognisable,
- If so, what is their relation to landscape at different scales,
- Whether it is possible to use information on 'peak ***migration*** activity' and '***migration*** flyways in the landscape' to avoid problems.

Research questions	**Methods**
• The investigation of collision rates of bats (like Brinkmann *et al.* 2011) for southern Europe, preferably one in south-western and another in south-eastern.	• Acoustic monitoring at nacelle height in combination with systematic collision mortality studies (methods after Arnett 2005, Grünkorn *et al.* 2005, Niermann *et al.* 2007, Brinkmann *et al.* 2011).
• Identifying habitats as important foraging sites for relevant bat species.	• Detector studies, • Habitat use modelling.
• Identifying ***migration*** routes/corridors on-shore and stepping stones. There are several studies on bat ***migration*** in different isolated places of Europe, but a continuous map of migration routes or stepping stones is not available. • Do landscape structures (river valleys, coastlines, valleys between mountain ridges, *etc.*) guide migration?	• Bat ringing projects along ***migration*** routes, • Constant effort mist netting along ***migration*** routes, • International genetic studies (see Petit & Mayer 2000), • Radio-tracking, • Radar studies, • Detector studies on selected ***migration*** points.

6.6 What is the behaviour of bats migrating over large water bodies, especially seas? In what numbers do they exhibit this behaviour?

Further information is needed on:

- Whether flyways / ***migration*** zones exist and are recognisable. If so, where locations of migration routes and hunting areas are, off-shore and near-shore.
- How can collision of bats with ***offshore turbines*** be determined?

Research questions	**Methods**
• Identifying migration routes/ corridors off-shore and stepping stones. There are several studies on bat migration in different isolated places of Europe, but a continuous map of migration routes or stepping stones is not available. Although some studies and anecdotal observations do show that bats are crossing the open sea such as the North and Baltic Seas (Ahlén 1997, Russ *et al.* 2001, 2003, Walter *et al.* 2004, 2007, Sonntag *et al.* 2006, Ahlén *et al.* 2009, Hüppop 2009, Meyer 2011, Seebens *et al.* 2013), specific information on the exact off-shore migration paths is missing.	• Bat ringing projects along migration routes, • Constant effort mist netting along migration routes (stepping stones), • International genetic studies (see Petit & Mayer 2000), • Radio-tracking, • Radar studies, • Detector studies on selected migration points.
• Is there bat activity offshore and at what distances from the shore? Which species are active offshore and is it only during migration? Does the migration also involve foraging and is it related to movements towards islands?	• Detector studies from lighthouses, buoys, boat transect (***manual detectors***, ***automated bat detector*** systems), • Thermal imaging, • Radar.
• Under which weather conditions do migrations take place on-shore/on-land and off-shore? More data is needed on bat migration, more specifically site-specific information of migration routes and the numbers of bats that use them, species-specific flight altitudes, and how timing, routing and direction are influenced by weather conditions. How often do bats stop to rest or forage?	• Detector studies from the ground, towers, wind turbines, balloons, *etc.*, • Thermal imaging camera studies, • Radar, • Physiological and behavioural studies.
• Develop and test methods to investigate bat activity and collision rates at ***offshore wind farms***.	• Tracking radar, • Boat transects, ferry tours, • ***Automated bat detector*** systems on buoys, rigs or other existing structures.

• Further development and testing of methods to investigate bat activity at sea.	• Radio tracking, • Tracking radar, • Ringing[4], • Broad-scale, repeated and synchronised bat detector samples, • Detector surveys on ferries and moored buoys.

6.7 Small wind turbines (SWT)

SWT of different types are relatively new phenomena, but numbers are increasing and it is likely this will continue. Very little is known about the effects on bat behaviour/bat populations, but work to date suggests that bats avoid operational turbines and observed mortality is relatively low (Minderman *et al.* 2012, Park *et al.* 2013). Further research is needed on mortality and disturbance impacts of a wider range of species, habitats and turbine sizes/models.

Research questions	Methods
• How does collision risk vary between species, habitats and turbine size/model? • Does the ***avoidance*** of turbines by *Pipistrellus* spp. previously observed apply to different species and/or turbines of different sizes? • Do SWT have a negative effect on species which are currently thought to be relatively unaffected by mid-size and large wind turbines?	• Acoustic monitoring in combination with systematic collision mortality studies (similar to Niermann *et al.* 2011) and/or behavioural studies; where possible, an experimental approach should be adopted (*e.g.* manipulation of turbine operation), • Thermal imaging.
• Are there any lethal- or sublethal effects when SWT are installed close to roosts?	• Acoustic monitoring in combination with roost counts.
• *What **mitigation** measures would be effective in reducing mortality and/or disturbance?*	• Experimental approach (before/after/control/impact) with manipulation of turbine operation.
• Is there potential for population level impacts from disturbance caused by SWT?	• Mortality and disturbance studies in combination with population modelling. • Case studies to take advantage of situations where turbines may have been installed adjacent to roosts/foraging areas of rare or vulnerable species.
• What is the potential for cumulative impacts of SWT?	• A searchable database of SWT installations is required at a county/country level.

[4] See also the EUROBATS Resolutions No. 4.6 and 5.5: Guidelines for the Issue of Permits for the Capture and Study of Captured Wild Bats.

7 Content of national guidelines

The volume, content and specificity of national guidelines, recently assessed in 2014 by the EUROBATS Intersessional Working Group on Wind Turbines and Bat Populations, vary to a high extent. They range from a few general recommendations to very detailed, thick documents. Some of the national guidelines are consistent with the EUROBATS Guidelines (published as EUROBATS Publication Series No. 3) while others stand to a greater or lesser extent in contradiction with them. In order to ensure equally effective protection of bats within the whole range of the Agreement, it is important that all national guidelines fulfil certain minimum standards, which are in agreement with the resolutions of Parties and the best current scientific knowledge.

In line with paragraph 5 of Resolution 5.6, approved by Parties during the 5th Session of the Meeting of Parties (2006), Parties should "develop appropriate national guidelines, drawing on the current version of the generic guidelines in Annex 1". This Resolution was later amended during the 6th Session of the Meeting of Parties (2010). In line with paragraph 6 of Resolution 6.11, Parties were urged to: "develop and ensure implementation of national guidance appropriate to the local environment based on the principles in the EUROBATS Publication Series No. 3". At the 7th Session of the Meeting of Parties (2014) this was confirmed and replaced by the paragraph 8 of Resolution 7.5, the text of which urges Parties and non-party Range States, if not already done so, to "develop and ensure implementation of national guidance following the most recent version of the EUROBATS Advisory Committee generic Guidelines annexed to the Resolution" (*i.e.* this document, until replaced by a new version).

A thorough examination of this provision, as well as other provisions of Resolution 7.5 leads to conclusions that:

1. Parties should (and non-party Range States are encouraged to) develop national guidelines on the planning process and impact assessments of wind turbines on bats.
2. National guidelines should be based on the principles contained in this publication.
3. Considering paragraph 5 of Resolution 7.5, it can be concluded that national guidelines should cover at least three issues:
   a) surveys,
   b) pre-construction impact assessments,
   c) post-construction monitoring.
4. Considering paragraph 6 of Resolution 7.5, if the issue is not regulated by national or regional law, national guidelines should also specify the requirements to be met by bat experts that undertake the pre- and post-construction monitoring and assessment of wind turbines impact on bats.
5. National guidelines should be specific to the local environment, *i.e.* they should adapt the general EUROBATS

Guidelines to local conditions (both at a national and, if possible, at a regional or even lower level).

6. Parties should also ensure implementation of national guidelines, hence during work on national guidelines care should be taken to ensure that they are executable, *i.e.* in agreement with national regulations and administrative practices, and take into account manpower and equipment resources of the national bat conservation community. At the same time, Parties should place the guidelines in the national system of ***environmental impact assessments*** to ensure that they are observed.

Even if the above recommendations look prescriptive, each of them is open to a range of interpretations. For this reason, below we analyse these points in detail, suggesting the minimum requirements for national guidelines and areas in which a range of national solutions are possible.

7.1 Developing national guidelines

Resolution 7.5 clearly indicates that Parties are urged to develop national guidelines concerning the planning process and impact assessments of wind turbines on bats. Non-party Range States are encouraged and advised to implement this Resolution for the conservation of European bat populations.

The Resolution does not specify the form of guidelines and it is recognised that various solutions are acceptable, depending on the preferences of a given state. Guidelines on wind farms may appear in a solely document concerning the issue of wind farms and bats (a solution that is applied most frequently), as a chapter in general guidelines for assessment of wind farm impact on the environment, or as a chapter on wind farms in general guidelines for assessing the impact of various development projects on bats.

It is also acceptable to develop separate guidelines for different elements of the process (such as pre-construction surveys, analysis of available data and research results, post-construction monitoring) and wind farm types (on-shore, off-shore, single turbines, small wind turbines, *etc.*). However, these individual guidelines should be consistent with one another and not lead to the unjustified reduction of assessment quality for one type of wind farm. As a rule, it should be ensured that, in line with paragraph 5 of Resolution 7.5, all wind farms that can have an impact on bats should be accompanied by pre-construction impact assessments (including adequate surveys) and post-construction monitoring, according to the same standardised practices. The number of bats killed by a turbine does not depend on whether it is a single device or whether it is in a group of turbines (Rydell *et al.* 2010a). Consequently, the ***cumulative effect*** of several single wind turbines can equal the impact of a large wind farm and hence it should require adequate research and assessments.

It can be assumed that the creation of several regional guidelines, rather than the national one, is acceptable, and if the sufficient consistency between them is ensured (see point 7.4).

7.2 Compliance of national guidelines with EUROBATS Guidelines

Parties should choose the appropriate authority/organisation to develop national guidelines. Typically, they are developed by specialised non-governmental organisations, but they can also be created by research institutions, nature conservation administrative units or even individual experts. However, because implementation of the provisions of the Resolution and nature conservation on the national scale is the duty of competent state authorities of a given Party, these authorities should ensure that the applied guidelines are in agreement with the current knowledge and the general EUROBATS Guidelines. Application of guidelines that do not fulfil these requirements should not be accepted.

The EUROBATS Guidelines contain both specific and general recommendations. National guidelines can, but do not have to, repeat specific recommendations. They can suffice in stating that the specific recommendations set in the EUROBATS Guidelines should be applied.

If the EUROBATS recommendations are too general, national guidelines should make them more specific. National guidelines can also regulate issues not mentioned in EUROBATS Guidelines.

Small deviations from EUROBATS recommendations are acceptable if they are based on:

a) special national or regional conditions – e.g. climate or species composition (for example, it is not necessary to carry out acoustic detection studies in March in states or regions in which March temperatures are below zero, or to search for wintering sites in states with a warmer climate in which bats do not hibernate);
b) current knowledge – in order to incorporate important new methods, widely accepted by bat researchers, which improve the effectiveness of research and impact assessments or mitigating measures, but are not yet included in the current version of EUROBATS Guidelines.

It should be noted that in line with Resolution 7.5, the EUROBATS Advisory Committee should keep the generic guidelines updated, taking into consideration advances in knowledge. This means that national guidelines should also be regularly updated, to keep them consistent with the most recent version of the EUROBATS recommendations and the current state of knowledge. A fixed frequency of updates of national guidelines can be adopted (e.g. every four years), however, it appears more effective to update them as necessary, but at least following each update of EUROBATS Guidelines. This means that guidelines should always contain the date of the last update or version number, which allows the user to identify the most current version.

7.3 The content of national guidelines

National or regional guidelines should cover at least pre-construction impact assessments, including surveys, as well as post-construction monitoring. Specific content of these guidelines, however, is determined mainly by their purpose. **National or regional guidelines should complement the general EUROBATS Guidelines, to en-**

sure that assessment of wind farm impact on bats takes into account specific conditions in a given state (or region). These conditions include mainly:

a) climatic conditions (those that affect the timing of the bat activity season),
b) natural conditions (land relief, types of habitats and their significance for bats),
c) characteristics of bat fauna (species, their distribution and abundance, population sizes, threats, vulnerability to collisions with wind farms, times and routes of ***migration***, *etc.*),
d) position of research and analyses in the national procedures of impact assessment (e.g. differences in research scope for the purposes of ***SEA, EIA*** and impact assessment on Natura 2000 sites; specific requirements concerning research and reports required by national regulations).

Taking into account that bats migrate over several countries and may suffer ***transboundary impacts***, their conservation requires a transboundary approach. Therefore, national guidelines should not be in contradiction to these guidelines. However, they can affect the choice of research methods (from among methods of similar effectiveness) and arrangement of reports, or create differences between requirements on data specificity on various stages of issuing a permission for construction of a wind farm in a given location. The scope of research and analyses can usually be more general at a strategic planning level and gradually more specific in the successive stages of the permission-issuing process, with the complete impact assessment analysis finished before a final decision to allow a wind farm construction is issued.

Natural characteristics (points a)-c)) can lead to small deviations from EUROBATS Guidelines, e.g. in order to better adapt research to bat activity and fauna in a given country. These modifications should, however, be based only on informed decisions and justified in the guidelines.

A. Minimum requirements concerning the scope and methods of surveys (pre- and post-construction) are set in EUROBATS Guidelines. National guidelines can also include recommendations e.g. concerning additional data sources, the applied equipment (in order to ensure comparability of results between countries or regions), method of choosing transects or detection points, requirements on the spatial representativeness of a study, limits of bat activity periods or requirements on the qualifications of persons or companies carrying out fieldwork and data analysis. It is recommended that they also specify (standardise) the scope of data that has to be submitted to the authority deciding on an impact assessment, as well as method of their presentation (e.g. type of map attachments or format of output data attached to the report) and storage (if this is not specified in other national regulations). National guidelines can differentiate recommendations for research by specific habitat types occurring in a given state. They can also suggest additional research, which is beyond the minimal scope set by EUROBATS Guidelines – obligatory, recommended or accepted in a given state.

B. Recommendations concerning pre-construction impact assessments should be specified in national regulations concerning assessment of impact on the environment, and in the case of Parties which are members of the European Union – also be compliant with EU legislation. It is crucial that national guidelines include the following:

1) minimum requirements on wind farm siting with regard to bats, to ensure clarity about which proposed wind farms are unacceptable (this can be decided on the basis of EUROBATS Guidelines, but national guidelines can also include additional recommendations, associated with specific local conditions - in line with paragraph 2 of Resolution 7.5);
2) an indication in which cases it is necessary to conduct an assessment of impact on a Natura 2000 site or other area or object of nature protection created for the purpose of bat protection;
3) types of recommended mitigating measures and principles of their application, with special consideration of the principles concerning the use of seasonal or temporal ***blade feathering***, increase of ***cut-in wind speeds*** and shutting down turbines temporarily, in line with paragraph 9 of Resolution 7.5.

C. National regulations regarding post-construction monitoring should consider the fact that, due to the possible changes in behaviour by bats associated with the construction of the wind farm, each wind farm requires post-construction monitoring. These requirements should indicate how results concerning the observed level of bat mortality and activity in the vicinity of rotors should translate into changes of recommendations for wind turbine operation (including both using more or less strict mitigating measures, or abandoning them if they are unnecessary). They should also specify that if it is not possible to decrease the mortality using mitigating measures, it is necessary to completely stop operation of wind turbines (at least during the period of bat activity). If application of mitigating measures is changed, national guidelines should specify the time and scope of further post-construction monitoring. National guidelines should also ensure that the results of post-construction monitoring are sent to appropriate authorities responsible for nature conservation and can be used by specialists for collective analyses and improvement of national and EUROBATS guidelines.

The above recommendations concerning the content of national guidelines do not form a closed list. These guidelines can also include other components, depending on the requirements of a particular state. Examples of such additional components are: experience requirements to be met by bat experts that undertake the pre- and post-construction monitoring and impact assessment, glossaries of terms used, lists of additional literature sources, list of organisations that can provide advice, and description of administrative procedures.

7.4 Adapting guidelines to local conditions

Currently, in most cases national guidelines cover the whole country (a Party or non-party Range State). However, there are cases (especially in the larger states) when different guidelines are adopted for different regions or administrative units. This is acceptable as long as differences between the regional guidelines are justified by local conditions (such as climate, land relief or bat fauna). Authorities responsible for observing EUROBATS Guidelines and bat conservation should ensure that all guidelines are as consistent between regions as possible. It is recommended that uniform, frame guidelines are set for the whole country, which caters for the local conditions in various regions (*e.g.* standardised research methods but regional differences in times of data collection or data interpretation).

In the case of states with similar natural conditions (e.g. small neighbouring countries) it is acceptable that uniform guidelines are adopted for a whole group of states. However, this should be unanimously approved by appropriate authorities of all the states in question. In other cases, in principle it is not accepted that guidelines developed for one state are applied also in a different state, especially if this leads to limiting the scope of research or adopting reduced criteria during interpretation of results. The only cases in which guidelines created in a different state can be applied, are the following:

a) if in the state for which an assessment is made, national guidelines have not yet been developed and adopted (in this case guidelines for the most similar state in terms of natural conditions and bat fauna can be applied);
b) to widen the scope of research relative to national guidelines, for scientific or comparative purposes, or e.g. near the national border, to do a cross-border impact assessment.

7.5 Ensuring implementation of guidelines

Implementation of national guidelines should be ensured by Parties. This can be done in two basic ways:

f) incorporation of the obligation to observe guidelines into national legislation;
g) incorporation of the guidelines in the authorization process for each project.

Besides this, it is essential to adopt consistent practices for evaluation of ***environmental impact assessment*** reports, in order to ensure that only the reports that comply with national guidelines are approved (studies with additional, broader scope or stricter interpretation of results can also be accepted).

With regard to EU member (or candidate) states, it should be emphasized that consistent application of the most recent national guidelines is also compliant with article 5, paragraph 1b of *Directive 2011/92/EU of the European Parliament and of The Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment* and with article 5, paragraph 2 of *Directive of the European Parliament and of the Council No. 2001/42/EC of June 27 2001 on the assessment of the effects of certain plans and programmes on the environment*. According to these regulations, the scope of required information (for the purposes of ***EIA*** or ***SEA***) should be consistent with the current state of knowledge and methods of assessment. National guidelines should specify the methods of assessment that are consistent with the current state of knowledge.

It is unacceptable if, when national guidelines are in place (are recommended officially by relevant administration authorities or non-officially by NGOs), projects are accepted for which no impact assessment was conducted, or it was conducted using different, independent methods, that are not in accordance with the guidelines, are reduced or require significantly less research (and yield less data to base a decision on) than the methods set in the national guidelines.

8 Conclusions and further work

This document sets out generic guidelines for the planning process and impact assessments to take account of the effect of wind turbines on bats. Additionally it summarises relevant research priorities. It is by no means complete and requires further development particularly within the European context.

The current impact of wind farms on bats should be investigated further in order to find solutions to minimise the impacts of future wind farm developments.

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10 Glossary

Automated bat detector – a system for recording bat echolocation calls that can be left unattended in the field.

Avoidance – action taken to avoid negative environmental impacts such as habitat loss, animal mortality or injury.

Bat activity index – a numerical value given in activity units (*e.g.* bat passes) per hour, determined for each survey at each listening point or functional transect section (as well as for the whole farm or its selected part), calculated separately for individual species or species groups (and for all bats); the term "mean bat activity index" can additionally be used, meaning a numerical value given in activity units per hour, determined for a selected period – e.g. for autumn migrations or the whole year – and calculated as the arithmetic mean of indices recorded in a given period or otherwise, in accordance with the applicable methodology.

Commuting – flight of a bat between a roost and a feeding area, or between two feeding areas or two roosts.

Compensation – action taken to address any residual negative environmental impacts such as habitat loss, animal mortality or injury that cannot be avoided or mitigated.

Conflict analysis – systematic study of the profile, causes, actors and dynamics of conflict.

Cumulative effect – combined effect on the environment caused by a proposed development in conjunction with other past, present and reasonable foreseeable developments and other human activities.

Cut-in wind speed – the wind speed at which a turbine begins to generate electrical power. It is model specific but generally between 2.5-4 m/s. Larger more modern turbines can be programmed very precisely to cut-in at higher wind speeds.

Distance from wind turbine – the shortest straight line distance between a given point or line and the horizontal circle with a centre at the wind turbine tower axis and a radius equal to the turbine blade length (approximate value).

Environmental impact assessment (EIA) – a national procedure for evaluating the likely environmental effects of those public and private projects which may have significant effects on the environment (see for instance Council Directive 85/337/EEC).

Feathering – adjusting the angle of the rotor blade parallel to the wind, or turning the whole unit out of the wind, to slow or stop blade rotation. The rotor is not fixed even during shutdown, but is permitted to spin freely at very low speed.

Habitats Directive – Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Manual bat detectors – a system for detecting bat echolocation calls allowing an operator to "hear", record or identify bats in the field.

Migration – regular, usually seasonal, movement of all or part of an animal population to and from a given area.

Mitigation – action taken to mitigate, reduce or minimize any negative environmental impact such as habitat loss, animal fatality or injury where it is not possible to avoid such impacts.

Offshore wind turbines – wind turbines located in the sea or other large bodies of water.

Onshore wind turbines – wind turbines located on land.

Precautionary principle – where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (United Nations – Rio declaration on environment and development 1992).

Repowering – increasing the generating capacity of a wind turbine site by fitting more efficient generators or blades to existing turbines, or replacing existing turbines with newer more efficient turbines. As technology has improved there is a general trend to replace older smaller turbines with fewer more efficient larger turbines. In Germany the term "repowering" refers only to replacement of smaller turbines to fewer new ones without increase of the generating capacity.

Scoping – the early and very important step in an assessment of environmental impact, which usually follows screening – the process of determining the content and extent of matters that should be covered in the environmental information to be submitted to a competent authority for projects or plans which are subject to EIA or SEA (usually scoping is used to identify at least: important issues to be covered in an assessment, the appropriate time and space boundaries of study, information necessary for decision-making, significant effects and factors to be studied in details, and sometimes also feasible alternatives to the proposed projects or plans, which should be reviewed).

Screening – the process of determination of whether or not an EIA is needed (usually it is based on country and/or EU legislation) – in the case of wind turbines it should take into consideration point 5 of the EUROBATS resolution 7.5, which requires the Parties to the Agreement to assess the impact of planned wind turbines on bats.

Small wind turbines (SWT) – there is no globally accepted definition of "small wind turbines" but the upper limit of individual countries' definitions typically range from 15-100 kW generational capacity (World Wind Energy Association 2013). A distinction is sometimes made between micro-wind (0-1.5 kW), small (1.5-50 kW) and medium wind (50-100 kW) turbines (Renewables UK 2012).

Strategic environmental assessment (SEA) – procedure for integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development (see for instance Directive 2001/42/EC).

Swarming - "autumn swarming" by some species of vespertilionid bats (particularly *Myotis, Plecotus, Eptesicus* spp. and *B. barbastellus*) occurs from late summer to autumn. *Pl. auritus* performs a "spring swarming" as well. Bats may travel many kilometres to underground "swarming sites", arriving several hours after dusk, and flying in and around the site and departing before dusk. Some swarming sites may also be used as hibernacula later in the year. Swarming ("dawn swarming") also refers to the circling flight pattern of some bat species that occurs outside the entrance to a roost (especially maternity roosts) before the bats enter at dawn.

Supporting infrastructure for the wind farm – includes access roads, substations and the grid connection cables, which may be overground or underground and may even include separate meteorological masts on larger wind farms to allow accurate monitoring of performance.

Transboundary impact – any impact caused by an activity situated in one country, and affecting the area under the jurisdiction of another country or countries.

Acknowledgements

We thank Eeva-Maria Kyheröinen, Joana Bernardino, Katherine Walsh, Frank Adorf, Michel Perret, Paul Racey, Primož Presetnik, Rita Bastos and Robert Raynor for their very valuable comments and contributions to this document. We are grateful to Jean Matthews (Natural Resources Wales, UK) for her generous help with the review of the text and to Suren Gazaryan (EUROBATS Secretariat) for his assistance in the final stages of the Guidelines' preparation.

Annex 1: **Studies done in Europe (update to Table 1 of EUROBATS Publication Series nº 3)**

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Albouy (2010), Roque-taillade, Aude, France	15 May - 30 September 2009	Open landscape (pastures with shrubs and scattered trees, some cereal fields)	8 WTs x 660 kW tower 47m; rotor ø 47m. 20 WTs x 850 kW tower ? ; rotor ø 52m	AS: analysis of 148 hours of recordings MM: no data	AS: 108 Pkuh/Pnat, 157 Ppip, 147 Tten, 36 Hsav, 4 Pspp. MM: 17 Hsav, 6 Ppyg, 5 Ppip, 1 Pspp., 1 N/i
Albrecht & Grünfelder (2011), Landkreis Neu-stadt an der Waldnaab in Bayern, Germany	16/17 July 2009; 19/20 August 2009	Ca. 630 m, Agricultural area, close to a mixed forest	no data	AS: batcorders registered the bat calls synchronously in three different heights (helium balloon at the height of prospective rotor blades and at 20m, 2m high on a pole)	Calls of Enil, Ppip, Pnat, Ppyg and Mmys/Mbra. Probably also Vmur
ALEPE (2012), Chastel-Nouvel, Rieutort de Randon et Servières (Lozère 48), France	24 April - 20 October 2008; 25 August - 07 October 2009; 26 July - 22 September 2010	Conifer plantations, Scot pines and birches, pastures in between	7 WTs x 2000 kW tower 80 m; rotor ø 82m	MM: 2008: 22 controls (1/8,18 days), 2009: 22 controls (1/2 days) 2010: 27 controls (1/2,19 days) SAR 60 m, SET.	2008: 6 carcasses (5 Ppip, 1 Nlei) 2009: 20 bats (9 Ppip, 4 Nlei, 1 Hsav, 6 N/i). 2010: no dead bats found MR: no cor-rection for surface as all mortalities were within 15 m from tower. MR: 5 estimators tested, Huso's formula seems the most accurate, 2008: 5,9-6,4/WT/7,9 weeks. 2009: 14/WT/5, 4 weeks. 2010: 0/WT/8,3 weeks
Allouche (2011), Mas de Leuze, France	12 July - 01 October 2011	Grassland, shrubs, 30% cereal crops	9 WTs x 800 kW ; tower 50m	MM: control every 3 days under 8 WTs. Access to 1 impossible. SAR 40m, SET. No surface correction as 100% except one 95%. 8 WTs regulated (4 at a time with 4 control WTs) with the Chirotech system (7 weeks of regulation, 7 periods)	54 dead bats (only 51 during the control period). For the considered period estimated number of killed /WT 82.15 (Erickson's formula) *i.e.* 4.5 less in 2011 than in 2009, but number of retrieved /WT only 1.4 less in 2011. Calculated production loss < 0.15% (Biotope)
Alves *et al.* (2006a), Chão Falcão I, Portugal	March - November 2005	Shrubs, eucaliptus	15 WTs	MM: searches twice/month; SAR 46 m; SET (spring, summer, autumn).	No dead bats found
Alves *et al.* (2006b), Candeeiros I, Portugal	March - November 2005	Shrubs, eucaliptus, pine	26 WTs	as above	1 dead bat (Msch); MR 0,65/WT/year (9 months period)
Alves *et al.* (2007a), Freita I e II, Portugal	August - October 2006	Shrubs, pine	16 WTs	Weekly searches; SAR 50 m; SET (spring).	4 dead bats: 2 Ppip, 1 Ppip/Ppyg, 1 Tten; MR0,4/WT/year (3 months period)
Alves *et al.* (2007b), Candal/Coelheira, Portugal	March - October 2006	Shrubs, low density pine areas	20 WTs	Weekly searches; SAR 50 m; SET (autumn).	29 dead bats: 13 Ppip, 4 Hsav, 9 Nlei, 1 Nspp., 1 Tten, 1N/i. MR 6/WT/year (8 months period)
Alves *et al.* (2007b), S. Pedro, Portugal	March - October 2006	Shrubs	5 WTs	as above	15 dead bats: 4 Ppip, 2 Pspp., 5 Nlei, 4 N/i.MR 12/WT/year (8 months period)
Alves *et al.* (2009a), Pinhal Interior (Furnas), Portugal	March - October 2006 - 2007	Shrubs	6 WTs	Weekly searches; SAR 46 m; SET (spring, summer, autumn).	2006: No dead bats found2007: 1 Hsav; MR 1,41/WT/year (8 months period)
as above	March - October 2006 - 2007	Shrubs	18 WTs	as above	No dead bats found
as above	March - October 2006 - 2007	Shrubs	6 WTs	as above	2006: 1 Pkuh; MR 1,41/WT/year (8 months period) 2007: no dead bats.
Alves *et al.* (2009b), Gardunha, Portugal	August - October 2007	Shrubs, pine	16 WTs in August, 17 in Sep-tember, 26 in October	as above	5 dead bats: 3 Ppip/Ppyg, 1 Pkuh, 1 Hsav; MR 3,8/WT/year (3 months period).
Alves *et al.* (2010), Pinhal Interior (Proença I e II), Portugal	March - October 2007	Shrubs, pine	21 WTs	as above	2 dead bats (Ppip + Nlei), MR 0,8 /year (8 months period).
Aminoff *et al.* (2014), Finland	May - October 2014	Gravel, schrub, dense bushes	15 WTs	MM: searches every 3 weeks, in autumn migration period on two consecutive days. SAR 50 m or 30 m (for small turbines), divided into sectors. SET to categorize habitats.	2 dead bats (Enil), no MR calculated.

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Amorim (2009), Candal Coelheira, Portugal	2007	Ridge NW-SE, range altitude 1000-1200m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and outcrops	20 WTs	MM: SAR 60 m. Control of 7 among 7 days of all WTs, SET; mortality search and space use by bats	48 carcasses (14 Nlei; 24 Ppip; 10 others). MR 9,55/WT (most of it on the end of summer). Relation between space use and mortality
Amorim *et al.* (2012), Freita and Arada Hills, NW Portugal	March - October 2007 (except July)	WFs along two parallel ridges 1400 m apart and at 1050–1150 m a.s.l. Low and sparse scrubland, scattered rocky areas. Within 190–3300 m from the WF, there are three water bodies and two abandoned mining complexes. The mines are classified as bat roosts of national importance due to the presence of large hibernating colonies of five bat species.	20 WTs in two WFs (10 each in WF I and WF II), 2 MWt model, tower 68m, blades with 32.8 m length.	MM: Carcass searches at WF I and WF II were done weekly on two consecutive days in the morning following bat acoustic sampling, in a 50 m SAR around each of the 20 WTs. Searchers followed random transects walked at a low speed over 30 min (or 15 min with 2 searchers). Within each search plot, 3 visibility classes (High, Medium and Low) and non-sampling areas were mapped (GIS) following the protocol of Arnett *et al.* (2005). All carcasses found were collected and frozen to allow for further identification. Carcass position was determined using a GPS, a 50-m tape and a military compass, the visibility class was registered. AS: weekly, started 45 min after sunset for the following three hours (10-min survey at each sampling point). 20 acoustic sampling points were defined (one per WT, each at a distance of 25 m from the WT, at a randomized azimuth). WF I and WF II were surveyed on two consecutive days, with randomized order of sampling points visited. To determine bat activity, the number of bat passes during the sampling period was counted. Bat activity was recorded with a BD (D240X, Pettersson Elektronik) connected to a digital recorder, at ground level only. Sampling was done only on nights without rain, fog or strong winds (more than 3.5 m/s at ground level). Bat vocalizations were analysed using sound-analysis software.	MM: 48 dead bats (573 carcass searches; mean bat mortality of 0.08 ± 0.18 carcasses/sample). 2 Hsav,14 Nlei, 25 Ppip, 4 Pspp., 4 N/i. AS: 838 bat passes recorded - mean bat activity 5.90 ± 11.3 bat passes/sample. 422 bat passes were identified: 12% Nlei, 58% Pspp. Species detected: Eser, Hsav, Mbly, Mmyo, Nspp., Nlei, Pkuh, Ppip, Pspp., Plspp., Tten.
Aves environnement & GCP (2009), St-Martin-de-Crau, France	15 March - 30 September 2009	grassland, shrubs and 30% cereal fields	9 WTs	MM: searches every 3 days (15/03-15/05 and 16/08-30/09) and once a week (16/05-15/08). Tests for predation (4) and detectability (4) and correcting factor for the non-controlled surface (crops)	100 dead bats (90% Pspp. and 1 Tten, 1 Mema and the others N/i yet)
Bach & Bach (2008), Germany	15 July - 15 October 2008	North Sea coast	ENERCON E-33, 3 WT	MM: searches every 3 days; Search area: 40 m around WT; SET.	MR: 3,1 /Year
Bach & Bach (2010), Germany	15 July - 15 October 2009	North Sea coast	ENERCON E-33, 7 WT	as above	MR: 1,6 /Year
Bach & Bach (2012), Ellenserdammersiel near Varel, Germany	01 July - 15 October 2012	Grassland, cattle and horse grazing	5 WTs, 3 Nordex, tower 90m, rotor ø 90m	MM: 36 days of control, every 3 days (morning, 45 min per WT) under 5 WTs. SAR 50 m (except for areas with dense vegetation); SET. AS at 3 WTs with AnaBat-SD1 per WT (rotor heigt), 108 nights.	5 dead bats (4 Pnat, 1 Nnoc) found. MR: probably 3.2/WT/study period. AS: Nnoc, Eser, Ppip, Pnat, Ppyg
Bach & Bach (2013a), Wiesmoor, Germany	30 April - 31 October 2012 (169 nights)	Agricultural area	5 WTs, ENERCON E 82, tower 102m, rotor ø 82m.	MM: as above. AS with two AnaBat-SD2 per WT (4m and rotor height)	No dead bats found. AS: calls of Nnoc, Nlei, Eser, Ppip, Pnat, Ppyg, Mdas, Plspp.
Bach & Bach (2013b), Friesland, Germany	29 June - 15 October 2012; 30 June - 15 October 2013 (215 nights)	Agricultural area, pastures	5 WTs, Nordex, tower 90m, rotor ø 90m.	MM: as above. AS around two WTs with Avisoft Recorder System	13 dead bats (10 Pnat; 3 Nnoc). MR: probably 4,2/WT/year. AS: Nnoc, Eser, Ppip, Pnat, Ppyg.

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Bach & Bach (2013c), Friesland II, Germany	01 March - 15 May 2013; 2 WT: 11 July - 15 October 2013; 2 WT: 01 August - 15 October 2013	Agricultural area, pastures	4WTs, REPower; tower 98m; rotor ø 104m	MM: as above, under 4 WTs. Search area of 50m radius around the WT (except for areas with dense vegetation); SET. AS at 4 WTs with Anabat SD1	8 dead bats (6 Pnat; 2 Nnoc) found. MR: probably 3,6/WT/ year. AS: Nnoc, Eser, Ppip, Pnat, Ppyg.
Bach & Bach (2013d), Wiesmoor, Germany	24 May - 31 October 2012 (165 nights)	Agricultural area	6 WTs, ENERCON E 82, tower 102m, rotor ø 82m.	MM: as above, under 6 WTs. AS with two AnaBat-SD2 per WT (4m and rotor height)	3 dead bats (3 Pnat) found. MR: probably 2,7/WT/year. AS: Nnoc, Nlei, Vmur, Eser, Ppip, Pnat, Ppyg, Plspp.
Bach *et al.* (2011a), Wiesmoor, Germany	24 May - 31 October 2011 (165 nights)	Agricultural area.	6 WTs, ENERCON E 82, tower 102m, rotor ø 82m.	as above	3 dead bats (Pnat, 2 Eser) found. MR: probably 2/WT/year. AS: Nnoc, Nlei, Eser, Ppip, Pnat, Ppyg, Plspp.
Bach *et al.* (2011b), Timmeler Kampen near Bagband, Germany	29 March - 01 October 2011	Agricultural area with few hedges and trees.	18 WTs, 3 ENERCON E 82, tower 108m, rotor ø 82m and 15 E66, tower 98m.	MM: 26 days mortality control, every 3 days (morning, 20 min per WT) under 18 WTs. SAR 50 m (except for areas with dense vegetation); SET. AS: 217 nights at 3 WTs with two AnaBat-SD1 per WT (4m and rotor height).	2 dead bats (Mdas, Nnoc). MR: probably 0.4/WT/study period. AS: calls of Nnoc, Eser, Ppip, Pnat, Ppyg, Mspp.
Bach *et al.* (2014), Walsrode, Germany	15 July - 15 October 2013 (91 nights)	Agricultural area	12 WTs, Nordex N-100, tower 100m, rotor ø100m.	MM: every 3 days under 7 WTs. SAR 50 m (except for areas with dense vegetation). SET. AS at two WTs with Avisoft Recorder System	21 dead bats (12 Pnat; 3 Ppip, 1 Ppyg, 5 Nnoc). AS: Nnoc, Nlei, Eser, Ppip, Pnat, Ppyg, Plspp.
Bach & Niermann (2010a), Germany	April - November 2009	Mixed landscape with farmland and forest	Vestas V 100, 6 WT	MM: searches every 2 days during spring and autumn migration period; summer period searches every 3 days; SAR 50 m; SET.	MR 4 /Year
Bach & Niermann (2010b), Langwedel, Germany	01 April - 31 November 2009; 01 April - 31 November 2010	Agricultural area and mixed forest	5 WTs (Vestas V90 tower 125m; rotor ø 90m	MM: every 2 resp. 3 days under 5 WTs. SAR 50m (except for areas with dense vegetation); SET. AS with one AnaBat SD1 per WT (at rotor height).	11 dead bats (7 Nnoc, 3 Pnat, 1 Nlei) found. MR: probably 2 resp. 4/WT/year . AS: Nnoc, Nlei, Eser, Ppip, Pnat, Ppyg.
Bach & Tillmann (2012), Belum, Cuxhaven, Germany	April - October 2012	Mean alt. 3m. Grassland	2 WTs (2MW), (AN BONUS tower 69m; rotor ø 76m)	MM: as above, under 2 WTs. AS: as above	12 dead bats (1 Pspp., 8 Pnat, 1 Ppip, 1 Nlei, 1 Nnoc): MR: 8.5/WT/6 month or 4.2/MW/6 month
Barreiro *et al.* (2007), Candeeiros I, Portugal	March - October 2006	Shrubs, eucaliptus, pine	26 WTs	MM: weekly searches; SAR 46 m; SET (spring, summer, autumn).	3 dead bats (Pspp., Nlei,1 N/i); MR 0,5/WT/year (8 months period)
Barreiro *et al.* (2007), Candeeiros II, Portugal	September - October 2006	Shrubs, eucaliptus, pine	11 WTs	as above	no dead bats
Barreiro *et al.* (2009), Mosqueiros I, Portugal	May - October 2008	Shrubs	4 WTs	MM: weekly searches; SAR 50 m; SET (autumn).	2 dead bats (Ppip + Tten), MR 3,6/year (6 months period)
Beucher *et al.* (2013), Castelnau-Pegayrols, Aveyron, France	2009 - 2012	Forested ridge and pastures; 1075-1090m	13 WTs, Enercon E70 (of 2.3 MW), tower 65m, rotor ø 71m	MM 2009 (35 visits): once a week last May fortnight, first week in June and last 2 weeks in September; 2 controls/ week from 05/06 to 20/09. MM 2010 (40 visits): once a week in May and last week in September; twice a week from 31/05 to 24/09. MM 2011 (36 visits): from 18/05 to 30/09: once per week in May, twice per week in June, July, August and September. MM 2012 : every day under 2 WTs, July-October (EXEN). SET (3 years). AS at nacelle height: 2009-2011	2009: 98 fatalities: 2 Hsav, 15 Pkuh, 57 Ppip, 9 Pspp., 1 Vmur, 7 Nlei, 2 Nlas, 4 Ppyg. 2010: curtailment at 6.5 m/ sec and security lights switched off: 2 fatalities (Ppip). 2011: curtailment at 5.5 m/sec and security lights switched off: 3 fatalities (2 Ppip, 1 Pkuh). 2012: curtailment for 2 WTs and different BDs in the nacelles; 4 fatalities (Ppip) under these WTs
Beucher & Lecoq (2009), France	15 June - 15 October 2008	Plateau with crops, intensive grasslands and some hedgerows	6 WTs VESTAS V90	MM: search around WTs (100m x 100m), twice a week with SET	10 dead bats (7 Ppip, 1 Pkuh, 1 Ppip/Ppyg, 1 N/i): 1 in June, 3 end of July, 5 in August, 1 mid-October
BFL (2011a), Ober-Flörsheim (Landkreis Alzey-Worms), Germany		Open agricultural area, low altitude	4 WTs: GE; NEC-Micon; Enercon. (towers: 68m; 68m; 80m rotor ø: 38m; 38m; 70m)	MM: SAR 50 m., daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	2 dead bats: 1 Nlei, 1 Ppip.
BFL (2011b), Naurath (Landkreis Trier-Saarburg), Germany		Mountain forest	1 WT: Enercon E 70 (tower: 85m, rotor ø: 70m)	as above	No dead bats found

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
BFL (2011c), Lingerhahn (Rhein-Hunsrück-Kreis), Germany		Mountain forest	2 WTs: REpower MM92 (tower: 100m, rotor ø: 92.5m)	as above	No dead bats found
BFL (2011d), Uhler (Rhein-Hunsrück-Kreis), Germany		Mountain forest	2 WTs: Vestas V90 (tower: 105m, rotor ø: 90m)	MM: SAR 50 m, daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	No dead bats found
BFL (2011e), Wörrstadt-Ost (Landkreis Alzey-Worms), Germany		Open agricultural area, low altitude	2 WTs: Enercon E 82 (tower: 135m, rotor ø: 82m)	MM: SAR 50 m, daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	2 dead bats: 1 Ppip, 1 Nlei.
BFL (2012a), Beltheim (Landkreis Rhein-Hunsrück), Germany		Mountain forest	1 WT: Enercon E 82 (tower: 138m, rotor ø: 82m)	as above	1 dead bat: Nlei.
BFL (2012b), Elmersberg (Landkreis Neunkirchen), Germany		Mountain forest	1 WT: Enercon E53 (tower: 73m, rotor ø: 53m)	AS with Batcorder. No MM.	No dead bats found
BFL (2012c), Mainstockheim (Landkreis Kitzingen), Germany	2011	Open agricultural area, low altitude	1 WT: Vestas V90 (tower: 105m, rotor ø: 90m)	as above	No dead bats found
BFL (2012d), Repperndorf (Landkreis Kitzingen), Germany	2009 - 2011	Open agricultural area, low altitude	1 WT: Vestas V90 (tower: 105m, rotor ø: 90m)	as above	No dead bats found
BFL (2013a), Naurath (Landkreis Trier-Saarburg), Germany		Mountain forest	1 WT: Enercon E 70 (tower: 85m, rotor ø: 70m)	MM: SAR 50 m, daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	No dead bats found
BFL (2013b), Bedesbach/ Welchweiler (Landkreis Kusel), Germany		Mountain forest	1 WT: Vestas V90 (tower: 80m, rotor ø: 90m)	AS with Batcorder. No MM.	No dead bats found
BFL (2013c), Kleeberg (Landkreis Neuenkirchen), Germany	2012	Mountain forest	1 WT: Enercon E53 (tower: 73m, rotor ø: 53m)	AS with Batcorder. No MM.	No dead bats found
BFL (2013d), Beltheim (Landkreis Rhein-Hunsrück), Germany	2011 - 2012	Mountain forest	1 WT: Enercon E 82 (tower: 138m, rotor ø: 82m)	MM: SAR 50 m, daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	1 dead bat: Nlei.
BFL (2013e), Gabsheim (Landkreis Alzey-Worms), Germany	2012	Open agricultural area, low altitude	2 WTs: Enercon E 101 (tower: 138.5m, rotor ø: 101m)	as above	2 dead bats: 1 Ppip, 1 Pnat.
BFL (2013f), Heimersheim (Landkreis Alzey-Worms), Germany	2012 - 2013	Open agricultural area, low altitude	3 WTs: REpower 3.4M104 (tower: 128m, rotor ø: 104m)	as above	2 dead bats: 2 Nlei.
BFL (2013g), Lingerhahn (Rhein-Hunsrück-Kreis), Germany	2011 - 2012	Mountain forest	2 WTs: REpower MM92 (tower: 100m, rotor ø: 92.5m)	as above	No dead bats found
BFL (2013h), Mainstockheim (Anlage A3) (Landkreis Kitzingen), Germany	2012	Open agricultural area, low altitude	1 WT: Vestas V112 (tower: 140m, rotor ø: 112m)	AS with Batcorder. No MM.	

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
BFL (2013i), Neuerkirch (Landkreis Rhein-Huns-rück), Germany	2012 - 2013	Mountain forest	3 WTs: Enercon E 82 (tower: 138m, rotor ø: 82m)	MM: SAR 50 m., daily - over a period of ten days per month with SET: correction for searched area every 2 months. AS with Batcorder.	No dead bats found. WF worked with algorithm (April - October), after the monitoring that algorithm was confirmed
BFL (2013j), Schorns-heim (Landkreis Alzey-Worms), Germany	2012	Open agricultural area, low altitude	2 WTs: Kenarsys K 100 (tower: 135m, rotor ø: 100m)	as above	No dead bats found
BFL (2013k), Unzenberg (Landkreis Rhein-Huns-rück), Germany	2012	Mountain forest	3 WT: 2 Vestas V112, 1 REpower 3.4 (towers: 142m, rotor ø: 142m?; 128m)	as above	No dead bats found
BFL (2013l), Waldal-gesheim (Landkreis Mainz-Bingen), Germany	2011 - 2013	Mountain forest	3 WTs: 2 Enercon E 82 (tower: 138m, rotor ø: 82m), 1 Enercon E 10 (tower: 138m, rotor ø: 101m)	as above	5 dead bats: Nlei, 4 Ppip.
BFL (2013m), Worms (Landkreis Alzey-Worms), Germany	2012	Open agricultural area, low altitude	1 WT: Vestas V112 (tower: 140m, rotor ø: 112m)	as above	1 dead bat: Pnat.
BFL (2013n), Wörrstadt-Ost (Landkreis Alzey-Worms), Germany	2011 - 2012	Open agricultural area, low altitude	2 WTs: Enercon E 82 (tower: 135m, rotor ø: 82m)	as above	2 dead bats: 1 Ppip, 1 Nlei.
BFL (2014a), Kirchberg (Rhein-Hunsrück-Kreis), Germany	2012 - 2013	Mountain forest	6 WTs: Enercon E 82 (tower: 135m, rotor ø: 82m)	as above	No dead bats found. WF worked with algorithm (April - October), after the monitoring that algorithm was confirmed
BFL (2014b), Gau-Bickelheim (Land-kreis Alzey-Worms), Germany	2012 - 2013	Open agricultural area, low altitude	3 WTs: Kenarsys K 100 (tower: 135m, rotor ø: 100m)	as above	3 dead bats: 2 Pnat, 1 Nlei.
BFL (2014c), Riegenroth (Rhein-Hunsrück-Kreis), Germany	2013	Mountain forest	1 WT: REpower 3.4M104 (tower: 128m, rotor ø: 104m)	as above	2 dead bats: 2 Pnat.
BFL (2014d), Hangen-Weisheim (Landkreis Alzey-Worms), Germany	2013	Open agricultural area, low altitude	2 WTs: REpower 3.4M104 (tower: 128m, rotor ø: 104m)	as above	1 dead bat: 1 Pnat.
BFL (2014e), Laubach III (Rhein-Hunsrück-Kreis), Germany	2013	Mountain forest	1 WT: Enercon E 101 (tower: 135m, rotor ø: 101m)	as above	2 dead bats: 2 Ppip, 1 Nlei.
BFL (2014f), Hochstät-ten (Landkreis Bad Kreuznach), Germany	2012 - 2013	Mountain forest	1 WT: Vestas V90 (tower: 105m, rotor ø: 90m)	as above	4 dead bats: 3 Ppip, 1 Vmur.
BFL (2014g), Schopfloch (Landkreis Freuden-stadt), Germany	2012 - 2013	Mountain forest	1 WT: Enercon E 82 (tower: 135m, rotor ø: 82m)	as above	2 dead bats: 2 Ppip.
Bio3 (2010), Serra do Mú, Portugal	January - December 2009	Mean alt. 530m. Cork oak forest	14 WTs (of 2,0 MW)	MM: monthly (Jan-Feb; Nov-Dec) and weekly searches (Mar-Oct) around 14 WTs. SAR 50 m; SET.	5 dead bats (2 Pkuh, 2 Nlei, 1 Espp.): 1 in February; 1 in May; 2 in June and 1 in July. MR: 0.80/WT/year
Bio3 (2011a), Cabeço Rainha 2, Portugal	March - October 2009	Mean alt. 1100m. Shrubs; pine forest	15 WTs (of 2,0 MW)	MM: weekly searches around all 15 WTs. SAR 50 m; SET.	4 dead bats (1 Nlei, 2 Eser, 1 N/i): 3 in August and 1 in Sep-tember; MR: 0,14/WT/8 months
Bio3 (2011b), Chão Falcão II, Portugal	Mid February - Mid November 2010	Mean alt. 410m. Shrubs; rock outcrop	11 WTs (of 2,3 MW)	MM: as above, around all 11 WTs.	5 dead bat (1 Ppip; 2 Pkuh; 1 Espp.; 1 N/i): 1 in August, 3 in September and 1 in November; MR: 0,52/WT/10 months

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Bio3 (2011c), Chão Falcão III, Portugal	April - October 2010	Mean alt. 450m. Shrubs; eucalypt plantation	9 WTs (of 2,3 MW)	MM: weekly around all 9 WTs made by man and dog. SAR 50 m; SET.	5 dead bats (3 Nlei; 1 Ppyg; 1 N/i): 1 in July; 1 in August; 2 in September and 1 in October. MR: 0,64/WT/7 months.
Bio3 (2011d), Lousã II, Portugal	September 2009 - October 2010	Mean alt. 950m. Shrubs; grassland; pine plantations; deciduous forest	20 WTs (of 2,5 MW)	MM: weekly around all 20 WTs (September-October 2009; April-October 2010). SAR 50 m.	No dead bats found
Bio3 (2011e), Serra de Bornes, Portugal	April - October 2010	Mean alt. 1100m. Shrubs; rock outcrops; hardwood forest	24 WT (of 2,5 MW)	MM: weekly around all 24 WT. SAR 50 m; SET.	4 dead bats (1 Ppip, 1 Pkuh, 1 Pspp. and 1 Tten): 1 in April, 1 in August, and 2 in September. MR: 0,25/WT/7 months
Bio3 (2011f), Serra do Mú, Portugal	January - December 2010	Mean alt. 530m. Cork oak forest	14 WTs (of 2,0 MW)	MM: monthly (Jan-Feb; Nov-Dec) and weekly (Mar-Oct) around 14 WTs; SAR 50 m; SET.	No dead bats found
Bio3 (2011g), Terra Fria - Contim, Portugal	August - November 2010	Mean alt. 1150m. Shrubs; grassland; rock outcrop; forest	5 WTs (of 2,0 MW)	MM: weekly around all 5 WTs. SAR 50 m; SET.	No dead bats found
Bio3 (2011h), Terra Fria - Facho-Colmeia, Portugal	April - November 2010	Mean alt. 1200m. Shrubs; grassland; forest	18 WTs (of 2,0 MW)	MM: weekly around 13 WTs. SAR 50 m; SET.	10 dead bats (2 Ppip/Ppyg; 4 Ppip; 4 Nlei): 2 in June; 2 in August; 6 in September. MR: 0,94/WT/8 months
Bio3 (2011i), Terra Fria - Montalegre, Portugal	April - November 2010	Mean alt. 1100m. Shrubs; grassland; forest; rock outcrop	25 WTs (of 2,0 MW)	MM: as above, around 19 WTs.	13 dead bats (1 Ppip; 1 Pkuh; 4 N/i, 5 Nlei; 1 Hsav; 1 Eser): 1 in April; 1 in May; 1 in June; 4 in August; 5 in September and 1 in October. MR in 2010: 0,92/MW/8 months
Bio3 (2012a), Lousã II, Portugal	April - October 2011	Mean alt. 950m. Shrubs; grassland; pine plantations; deciduous forest	20 WTs (of 2,5 MW)	MM: weekly around all 20 WTs (September-October 2009; April-October 2010). SAR 50 m. AS: monthly, from April to October (10-min survey at each sampling point; n=16). Bat activity was recorded at ground level with D240X, Pettersson Elektronik connected to a digital recorder. Bat vocalizations were analysed using sound-analysis software.	AS: 3 Bbar, 2 Hsav, 2 Mesc, 6 Eser/Eisa, 2 Nlei/Eser/Eisa, 2 Nlas/Nnoc, 1 Nlei, 1 Ppip, 27 Ppip, 27 Ppip/Ppyg, 4 Ppyg, 1 Ppyg/Msch. Shelters: no monitoring. MM: no dead bats found
Bio3 (2012b), Chão Falcão II, Portugal	February - November 2011	Mean alt. 410m. Shrubs; rock outcrop	11 WTs (of 2,3 MW)	MM: weekly around all 11 WTs. SAR 50 m; SET. AS: as above (n=34).	AS: 2 Eser/Eisa, 56 Nlei/Eser/Eisa, 5 Nspp., 106 Ppip, 43 Ppyg / Msch, 1 Pkuh, 57 Pspp., 5 Plaus/Paur, 6 Rhip, 24 Tten. Shelters: 20 bats (N/i) probably of Rfer, Rhip, Rmeh/Rhip, Ppyg/Msch, Ppip/Ppyg and/or Nlei/Eser/Eisa. MM: no dead bats found
Bio3 (2012c), Chão Falcão III, Portugal	April - October 2011	Mean alt. 450m. Shrubs; eucalypt plantation	9 WTs (of 2,3 MW)	MM: weekly around all 9 WTs made by man and dog. SAR 50 m; SET. AS: as above (n=28)	AS: 26 Nlei/Eser/Eisa, 11 Plaus/Paur, 2 Pkuh, 30 Ppip, 8 Ppyg/Msch, 12 Pspp., 1 Rmeh/Rhip. Shelters: 26 Reur/Rmeh, 1 Rhip, 1 Rfer, 1000 Msch, 40 Mmyo/Mbly, 300 Mmyo, more than 20 N/i probably of Rhip, Rfer, Rmeh/Rhip, Ppyg/Msch, Nlei/Eser/Eisa. MM: 1 Pspp., 1 Ppip/Ppyg, 1 Nlei, 1 Ppip. MR (Jain *et al.* 2007 / Huso 2010 / Korner-Nievergelt *et al.* 2011): 1,7/1,0/1,2/WT in 2011
Bio3 (2012d), Nave, Portugal	January - December 2011	Mean alt. 1000m. Shrubs; rock outcrops	19 WTs (of 2,0 MW)	MM: weekly around all 19 WTs. SAR 50 m; SET. AS: as above (n=20).	AS: 2 Eser/Eisa, 1 Nlei/Eser/Eisa, 1 Plaur/Plaus, 7 Pkuh, 9 Ppip, 4 Ppip/Ppyg, 1 Ppyg, 5 Tten. Shelters: no shelter monitoring MM: 2 Hsav, 3 Pkuh, 2 Ppip, 1 Ppip/Ppyg, 1 Nlei. MR (Jain *et al.* 2007 / Huso 2010 / Korner-Nievergelt *et al.* 2011): 0,6 / 0,3 / 1,6 /WT in 2011
Bio3 (2012e), Carreço-Outeiro, Portugal	April - October 2011	Mean alt. 430m. Shrubs; rock outcrops	6 WTs (of 2,0 MW)	MM: weekly around all 6 WTs in May, June, September and October. SAR 50 m; SET. AS: as above	AS: 1 Mmyo/Mbly, 1 Mspp., 25 Ppip, 6 Ppip/Ppyg, 2 Ppyg, 1 Pspp. Shelters: no shelter monitoring. MM: 1 Ppip, 1 Pkuh. MR (Jain *et al.* 2007 / Huso 2010 / Korner-Nievergelt *et al.* 2011): 33,3 / 8,6 / 6,3 /WT in 2011

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Bio3 (2012f), Terra Fria, Portugal	March - October 2011	Contim: mean alt. 1150m; shrubs; grassland; rock outcrop; forest. Facho-Colmeia: mean alt. 1200m; shrubs; grassland; forest; Montalegre: mean alt. 1100m; shrubs; grassland; forest; rock outcrop	5 WTs (of 2,0 MW) - Contim; 18 WTs (of 2,0 MW) - Facho-Colmeia; 25 WTs (of 2,0 MW) - Montalegre	MM: weekly around 37 WTs (Montalegre - 19; Facho-Colmeia - 13; Contim - 5). SAR 50 m; SET. AS: monthly, from March to October (10-min survey at each sampling point). Bat activity was recorded at ground level with D240X, Pettersson Elektronik connected to a digital recorder. Bat vocalizations were analysed using sound-analysis software.	AS: 6 Bbar, 5 Hsav, 1 Mmyo/Mbly, 3 small Mspp., 1 Mspp., 26 Eser/Eisa, 2 Nlei/Eser/Eisa, 12 Nlei, 2 Nspp., 1 Ppip, 59 Ppip, 7 Pspp., 1 Plspp., 2 Tten. Shelters: 90 Pspp.,15 small Mspp. MM: Montalegre - 3 Nlei, 1 Ppip, Facho-Colmeia - 2 Ppip; Contim - no mortality detected. MR (Jain *et al.* 2007 / Huso 2010 / Korner-Nievergelt *et al.* 2011): Montalegre - 2/ 2,8/1,4 / WT in 2011; Facho-Colmeia - 1,6 /2,3/1,2/WT in 2011.
Bio3 (2012g), Cabeço Rainha 2, Portugal	March - October 2010	Mean alt. 1100m. Shrubs; pine forest	15 WTs (of 2,0 MW)	Weekly searches around all 15 WTs; SAR 50 m; SET	2 dead bats (N/i): 1 in August and 1 in September; MR: 0,21/WT/8 months
Bio3 (2013a), Bornes, Portugal	April - October 2011	Mean alt. 1100m. Shrubs;rock outcrops; hardwood forest	24 WT (of 2,5 MW)	MM: weekly around all 24 WTs. SAR 50 m; SET. AS: monthly, from April to October (10-min survey at each sampling point; n=32). Bat activity was recorded at ground level with D240X, Pettersson Elektronik connected to a digital recorder. Bat vocalizations were analysed using sound-analysis software.	AS: 11 Bbar, 8 Eser/Eisa, 7 Hsav, 9 Mmyo/ Mbly, 2 small Mspp., 1 Mspp., 2 Nlei, 1 Nspp., 110 Pkuh, 41 Pkuh/Ppip, 394 Ppip/Ppyg, 62 Ppip/Ppyg/Msch, 10 Ppyg/Msch, 77 Pspp., 4 Plspp., 17 Tten. Shelters: 32 Rspp., 1 Rhip and several N/i. MM: 1 Ppip, 1 Hsav. MR (Jain *et al.* 2007 / Huso 2010 / Korner-Nievergelt *et al.* 2011): 1,18/1,19/0,79/WT in 2011
Bio3 (2013b), Mosqueiros II, Portugal	July 2011 - June 2012	Mean alt. 1080m. Shrubs; rock outcrops; oak forest	10 WTs (of 2,0 MW)	MM: weekly around all 10 WT. SAR 50 m; SET. AS: see above.	AS: 2 Mmyo/Mbly, 1 Mesc, 1 Mdau, 27 Ppip, 1 Ppyg, 1 Ppip, 9 Pspp., 1 Nlei, 1 Nlei/Eser/Eisa, 1 Nspp., 4 Eser/Eisa, 2 Plaur/Plaus, 5 Tten. Shelters: 11 Rfer, 17 Rfer/Reur/Rmeh, 4 Rhip. MM: 1 Tten, MR (Huso 2010): 0,34/WT in 2011.
Bio3 (2013c), Lousã II, Portugal	April - October 2012	Mean alt. 950m. Shrubs; grassland; pine plantations; deciduous forest	20 WTs (of 2,5 MW)	MM: weekly around all 20 WTs (September-October 2009; April-October 2010). SAR 50 m. AS: see above (N=16). Monitoring bat shelters: 1 shelter was found and iNspp.ted.	AS: 8 Bbar, 9 Eser/Eisa, 24 Eser/Eisa/Nlei, 1 Mmyo/Mbly, 1 Nlas/Nnoc, 6 Pkuh/Ppip, 26 Ppip/Ppyg, 72 Ppip/Ppyg / Msch, 12 Ppyg/Msch, 25 Pkuh, 32 Ppip, 4 Pspp., 2 Plaus/ Plaur, 4 Tten. Shelters: 1 Eser/Eisa/Nlei, 2 Rhip and 1 Ppip/ Ppyg/Msch. MM: No dead bats found.
Bio3 (2013d), Meroicinha II, Portugal	March 2012 - January 2013	Mean alt. 1280m. Shrubs; grassland; rock outcrops	6 WTs	MM: weekly around all 6 WTs (March-October 2012) and monthly in March, October and November of 2012. SAR 50 m. AS: as above (n=12). Monitoring of bat shelters: 28 bat shelters were found and iNspp.ted in each of the following periods: April to July and December.	AS: 1 Bbar, 1 Eser/Eisa, 8 Eser/Eisa/Nlei, 1 Mmyo/Mbly, 1 Nspp., 1 Ppyg/Msch, 23 Tten. Shelters: Mmys (~18); Mdau (~30); Tten (~70); small Mspp. (~51); Mdau/Mmys (~4); Mspp. (~6); Rfer (~4); Pspp. (at least 31). MM: no dead bats found.
Bio3 (2013e), Nave, Portugal	January - December 2012	Mean alt.: 1000m. Shrubs; rock outcrops	19 WTs (of 2,0 MW)	MM: weekly searches around all 19 WT. SAR 50 m; SET. AS: as above, at 20 sampling points	AS: 7 Bbar, 16 Eser/Eisa, 2 Eser/Eisa/Hsav, 2 Nlei/Eser/Eisa, 2 Hsav, 4 small Mspp., 2 Mmyo/Mbly, 8 Pkuh, 3 Pkuh/Ppip, 68 Ppip, 18 Ppip/Ppyg, 10 Ppip/Ppyg/Msch, 7 Plaur/Plaus, 5 Tten. Shelters: no monitoring. MM: 1 Nlei, MR (Huso 2010 / Korner-Nievergelt *et al.* 2011): 01/0,1/WT in 2012
Bio3 (2013f), Chão Falcão III, Portugal	April - November 2012; January 2013	Mean alt. 450m. Shrubs; eucalypt plantation	9 WTs (of 2,3 MW)	MM: weekly around all 9 WTs, made by man and dog. SAR 50 m, SET. AS: as above, at 28 sampling points. Monitoring bat shelters: 11 bats shelters were monitored by direct observation (whenever possible) or by ultrasound analysis of bats leaving the roosts.	AS: 18 Nlei/Eser/Eisa, 1 Nlas/Nnoct, 1 Pkuh/Ppip, 13 Ppip/ Ppyg, 6 Ppip/Ppyg/Msch, 1 Pkuhl, 1 Paus/Paur Shelters: 6 Rhip, Rfer (several individuals), 2 Rspp., 1 Mmyo/Mbly, 162 Mmyo, 18 Rmeh/Reur, 823 Msch, several individuals and groups of Rhip, Rfer, Rmeh/Rhip, Ppyg/Msch, Nlei/ Eser/Eisa, Nlas/Nnoc. MM: 2 Nlei, MR (Huso 2010/Korner-Nievergelt *et al.* 2011): 0,5/0,6/WT in 2012
Bio3 (2013g), Chão Falcão II, Portugal	February - October 2012	Mean alt. 410m. Shrubs; rock outcrop	11 WTs (of 2,3 MW)	MM: weekly searches around all 11 WTs. SAR 50 m; SET. AS: as above, at 34 sampling points. Monitoring bat shelters: 10 bats shelters were found and iNspp.ted in each of the following months: June, July, September and October.	AS: 2 Eser/Eisa, 2 small Mspp., 73 Nlei/Eser/Eisa, 4 Nspp., 8 Pkuh/Ppip, 76 Ppip/Ppyg, 14 Ppip/Ppyg/Msch, 2 Ppyg/ Msch, 1 Ppip, 14 Pspp., 2 Plaus/Plaur, 14 Tten. Shelters: 8 Rhip, more than 10 N/i individuals, several individuals and groups of Rhip, Rfer, Rmeh/Rhip, Ppyg/Msch, Nlei/Eser/Eisa, Nlas/Nnoc. MM: No dead bats found.

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Bio3 (2013h), Bornes, Portugal	April - October 2012	Mean alt. 1100m. Shrubs, rock outcrops, hardwood forest. .	24 WTs (of 2,5 MW)	MM: as above, around all 24 WTs. AS: as above, at 32 sampling points. Monitoring bat shelters: shelters known from previous years were monitored.	AS: Bbar (27); Eser/Eisa (5); Hsav (4); Mema/Mbec (1), Mesc (2), Mmyo/Mbly (4); 1 Mspp., Nlei/Eser/Eisa (2); Pkuh (53); Ppip (286); 2 Ppyg, Pspp. (165); Plaus/Plaur (7); Rfer (2); Rmeh/Rhip (1); Tten (8). Shelters: Rhip (2); 83 bat passes of Rfer, Reur, Reur/Rmeh, Mmyo, Rhip; Rspp. (1); 3 or 4 individuals of Ppip/Ppyg, Rmeh/Rhip, Rfer, Rhip, Reur/Rmeh, 1 Ppip, Hsav (1). MM: No dead bats found
BLG (2009), Nord-schwarzwald, Germany		Mountain forest (high altitude)	14 WTs: 12 Vestas V90, 2 Vestas V80 (tower 114 m, rotor ø 90 m; 80 m)	MM: SAR 50 m; SET every 2 month. AS with von Laar Avisoft real-time system.	18 dead bats: 11 Ppip, 4 Pnat, 2 Ppyg, 1 Vmur.
Brinkmann & Bontadina (2006): Ettenheim Mahlberg, Hochschwarzwald, Holzschlägermatte, and Rohrhardsberg, Freiburg, Germany	03 August - 28 October 2004; 02 April - 16 October 2005	Some WTs in forests, some on pastures (alt.: 470-1000m)	2004: 16 WTs (+16 WTs sporadically). 2005: the 8 WTs with the highest collision rates in 2004.	MM: every 5 days (30-50 min per WT). SAR 50 m (except for areas with dense vegetation); SET.	More dead bats at WTs in forests than at WTs in pastures. 50 dead bats found during study (39 Ppip, 8 Nlei, 2 Vmur, 1 Eser).
Brinkmann *et al.* (2011), Germany	July - September 2007 and 2008	5 different habitat types	72 WTs in 36 WFs	MM at 30 WTs, AS at rotor height with AnaBat-SD1 and Batcorder, and thermal imaging. Prediction of bat activity (by wind speed, time and month).	100 dead bats (Pnat, Nnoc, Ppip, Nlei) found during study period, on average 9.5/WT (min 0- max 57,5). MR 12/WT/year. Bat activity registered by AS corresponds (mostly) to activity seen in thermal imaging.
Cabral *et al.* (2008a), Outeiro, Portugal	Spring 2008	Ridge NE-SW, range altitude1186-1311m; totally integrated in an important area for the conservation of the biodiversity; low bushes	15 WTs	Efficiency, predation and controlled surface MM: SAR 60 m. Control of 7 among 7 days of all WTs.	MR 1,86/WT/year
Cabral *et al.* (2008b), Outeiro, Portugal	Summer 2008	As above	15 WTs	as above	MR 0,32/WT/year
Cabral *et al.* (2008c), Outeiro, Portugal	Autumn 2008	As above	15 WTs	as above	MR 2,28/WT/year
Cabral *et al.* (2008d), Outeiro, Portugal	Spring 2008	As above	15 WTs	Efficiency, predation and controlled surface	MR 1,86/WT/year
Cabral *et al.* (2009), Outeiro, Portugal	All seasons 2008	As above	15 WTs	MM: SAR 60 m. Control of 7 among 7 days of all WTs.	Total mortality estimated = 67,1 bats died between March and October 2008
Camina (2012), La Rioja, Soria and Aragón, Spain	2000 - 2010	Ebro River Valley. Lowlands (< 700 m a.s.l.): wine yards, crops, fruit cultivations, and Populus sp. plantations. Sistema Ibérico mountain range (up to 2,262 m a.s.l.): forest, pasture, shrubland, croplands, and pine plantations.	56 WFs	Bat fatalities reported in post-construction monitoring surveys from 56 WFs were reviewed. There were many deficiencies in their protocols that prevent comparisons with other studies nationally and internationally. Only five reports (9%) accounted for searcher efficiency or carcass removal biases. Survey data for La Rioja were provided by Dirección General del Medio Natural del Gobierno de La Rioja (monitoring period 2002–2008, 10 WFs), Junta de Castilla y León for Soria province (monitoring 2000–2008, 14 WFs). The Aragonese Local Government provided several bird and bat monitoring reports for the 2000–2007 period (32 WFs) located in Zaragoza, Huesca and Teruel provinces (all these unpublished reports are available on request from the author).	147 dead bats. 68 Ppip (59%), 16 Pkuh (14%), 21 Hsav (18%), 1 Bbar, 5 Nlas, 1 Nlei and 4 Tten (< 5% each). In the mostly low elevations sites in Aragon, fatalities occurred between March and December and peaked (76%) from July to October. In La Rioja and Soria, where WFs mostly are located at higher elevations, fatalities occurred between May and October and without any obvious late summer peak. Sex and age of the dead bats were not provided in any of the reports.

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Chatton (2011), St Genou (Indre), France	3 months 2010	Cereal fields	6 WTs Vestas V80	MM: once a week	5 Ppip
as above	6 months 2011	Cereal fields	6 WTs Vestas V80	MM: twice a week	5 Ppip; MR for 2011: 45/6WTs/6 months (but no correction for predation nor controlled surface)
Conduché *et al.* (2012), Charly s/Marne (02), France	12 controls 04 August - 20 October 2011	Crops. Only small woods at each end of the WT line.	11 WTs	MM: SAR 50 m, 5 m between transects, SET. AS in relation to wind speed, temperature and time after sunset	8 dead bats: 5 Ppip, 3 Nlei. MR for 3 months (Winkelman 1989): 26,16 Nlei and 30,41 Ppip
Cornut & Vincent (2011), Le Pouzin, Ardèche, France	05 May - 20 October 2010	River, grassland, shrubs/ wood, industrial estate	2 WTs x 2300 kW tower 85 m; rotor ø 90m	MM: 05/05-20/06 & 21/06-10/08: twice a week, every other day, 11/08-16/09 every 4th day, 17/09-20/10 every 4th day except in October: once a fortnight. SAR 56 m; SET, surface correction.	6 dead bats (1 Hsav,1 Pspp., 2 N/i, 1 Pkuh, 1 Nnoc). MR/WT/ year: 6.79 (Winkelman 1989), 54,93 (Erickson 2000), 75,99 (Jones 2009), 44,17 (Huso 2010)
Cornut & Vincent (2011), La Répara-Auriples, Drôme, France	05 May - 20 October 2010	Mixed forest, agriculture	2 WTs x 2300 kW tower 60 m; rotor ø 71m	MM: 05/05-20/06 & 21/06-10/08: twice a week every other day, 11/08-20/10 every other day. SAR 56 m; SET, surface correction.	42 dead bats (9 Ppip, 8 Pkuh, 7 Pspp., 6 Hsav, 5 Nlei, 1 Nnoc, 2 Pnat,1 Ppyg, 1 Msch, 1 Eser, 1 N/i). MR/WT/year: 130.49 (Winkelman 1989), 59.68 (Erickson 2000), 86.94 (Jones 2009), 79.17 (Huso 2010)
CSD Ingenieurs Conseils (2013), Southern Belgium	April - October 2013	Arable	5 WTs Vestas V90	MM: SAR 50 m, with measurement of predation and observer efficiency. Infrared camera recording of bat activity. AS: automated recording of bat ultrasounds.	10 dead bats found under 5 WTs. MR 8/WT/year, taking predation and search efficiency into account.
Ecosistema (2007), Lameira Portugal	2006 - 2007	Ridge S-N, mean altitude 1332m; totally integrated in an important area for the conservation of the biodiversity; shrubland	8 WTs	MM: efficiency, predation and controlled surface	MR 0,63/WT/year
Ferri *et al.* (2011), Fucino Valley and the Sirente-Velino Natural Regional Park, Abruzzo, Italy	15 March - 31 October 2009	Scrubland and hemi- cryptophytic pasture patches characterised by Brachypodium rupestre. Cerchio-Collarmele: along the southern slopes of the Sirente Massif, alt. 900-1150m. Cocullo: along a mountain ridge, alt. 1200-1600m.	46 WTs in 2 WFs. Cerchio-Collarmele: 21 WTs, Vestas V80, tower: 78m, rotor ø 80m and Cocullo: 25WTs, Gamesa 850 kW)	MM: every 3 days. Search area: permanent square plots, 120 m per side and centred on the WT (30-60min per WT).	7 dead bats found (6 Hsav, 1Ppip)
Frey *et al.* (2013), Timmeler Kampen near Bagband, Germany	29 March - 01 October 2012	Agricultural area with few hedges and trees	18 WTs, 3 ENERCON E 82, tower 108m, rotor ø 82m and 15 E66, tower 98m.	MM: 26 control days, every 3 days (morning, 20 min per WT) under 18 WTs. SAR 50m (except for areas with dense vegetation); SET. AS: 217 nights at 3 WTs with two AnaBat-SD1 per WT (4m and rotor height)	1 dead bat (Pnat). MR: probably 0.2/WT/study period. AS: Nnoc, Eser, Ppip, Pnat, Ppyg, Mspp.
Georgiakakis *et al.* (2012), East Macedonia and Thrace, Greece	August 2009 - July 2010 (248 days)	Main habitat types: forests (beech, oak and pine reforestations), sclerophyllous vegetation and alpine meadows. Other habitats: cultivated fields, pastures and rocky slopes.	88 WTs in 9 WFs (towers 44-60m, rotor ø 52-90m).	MM: 5-6 days per week around all WT (except 24 December 2009 to 11 March 2010: 20 days only)SAR 50 m, two fieldworkers. The WT platform was searched from a car moving in a circle. The rest of the plot was checked on foot. Each WT was visited alternately morning and midday to afternoon. When a bat was located, researchers recorded the code of the wind turbine, the distance to the tower base of the nearest turbine (n = 108 carcasses), the exact carcass position using GPS equipment and the date.	MM: 181 dead and 2 injured bats. 56 Nlei (31%), 53 Ppip/ Ppyg (29%), 35 Pnat (19%), 23 Hsav (13%), 10 Nnoc (5%), 1 Eser, 1 Nlas, 1 Vmur. Most killed bats were males (123 or 67%); most killed bats were adults (167 or 91%). The majority of fatalities were observed from May to September. Mean number of fatalities /WT/year: 2.08.
Gottfried *et al.* (2011), Szczecin Coast, Gdańsk Coast, Chełmsk-Dobrzyń Lakeland, South Wielkopolska Lowland, Sudetes Foothills, Poland	2007 - 2011	Farmlands and meadows in five regions	Towers 80m (one tower, Chełmsk-Dobrzyń Lakeland, 45m)	Review of all accessible data from 2007 to 2011	26 dead bats: 5 Nnoc, 12 Pnat, 1 Ppip, 1 Ppyg, 3 Eser, 3 Vmur, 1 Enil

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Gottfried & Gottfried (2012), Sudete Foothills, SW Poland	May - October 2012	Farmland	6 WTs: REpower MM92, 2 MW (tower 80m, rotor ø 92.5m)	MM: at 6 WTs. 7 controls, one control per month, check only technical square about 1350m².	27 dead bats: 11 Nnoc, 5 Nlei, 4 Pnat, 2 Ppip, 2 Pspp., 2 Vmur, 1 undetermined. Most of dead bats were found in August and September (93%)
Hortêncio *et al.* (2007), Caramulo, Portugal	April - October 2006	Shrubs, pine	13 WTs in April-June, 17 in July, 23 in August, 25 in September and October	MM: weekly. SAR 46 m; SET (spring, summer, autumn).	47 dead bats: 5 Ppip, 13 Pspp., 16 Nlei, 1 Nnoc, 12 no id.; MR 15,1/WT/year (7 months period)
Hortêncio *et al.* (2008), Chão Falcão I, Portugal	March - October 2007	Shrubs, eucaliptus	15 WTs	MM: weekly. SAR 46 m; SET (spring, summer, autumn).	3 dead bats (Ppip/Pkuh, Pkuh, Nlei); MR 1,3/WT/year (8 months period)
Hötker (2006)	60 publications (1989 - 2006)	Many different habitats	34 WFs. Tower: 22m to 114m; rotor ø 14m to 80m	"Meta analysis" of 45 studies from 60 publications (Belgium, Germany, Denmark, France, Netherlands, Great Britain, Austria, Spain, USA, Australia)	Calculated MRs per WT per year: between 0 and 103 (Freiamt Schillinger Berg 1, Germany) bats. Median: 6,4 bats. Mean:13,3; standard deviation: 13,3.
Korner-Nievergelt *et al.* (2011), Germany				Simulation study on a German dataset.	Formula for to determining the AS probability of birds or bats that are killed at WTs (based on carcass persistence rate, searcher efficiency and the probability that a killed animal falls into a searched area)
LEA (2009a), Sobrado, Portugal	Spring 2009	Ridge N-S, range altitude 1240-1290m; totally integrated in an important area for the conservation of the biodiversity; low bushes	4 WTs	MM: Control of 7 among 7 days of all WTs. SAR 60 m; SET.	No dead bats found
LEA (2009b), Sobrado, Portugal	Summer 2009	As above	4 WTs	as above	No dead bats found
LEA (2010a), Sobrado, Portugal	Autumn 2009	As above	4 WTs	as above	No dead bats found
LEA (com pess), Sobrado, Portugal	All seasons 2009	As above	4 WTs	as above	No dead bats found
LEA (2010b), Negrelo e Guilhado, Portugal	Summer 2009	Ridge N-S, range altitude 1000-1100m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and birchs	10 WTs	as above	MR 0,94/WT
LEA (2010c), Negrelo e Guilhado, Portugal	Autumn 2009	As above	10 WTs	as above	MR 0,46/WT
LEA (com pess), Negrelo e Guilhado, Portugal	Summer & Autumn 2009	As above	10 WTs	as above	MR 1,40/WT/2 seasons
LEA (2010d), Mafomedes, Portugal	2009	Ridge NE-SW, range altitude 1075-1110m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and pine stand	2 WTs	MM: Control of 15 among 15 days of all WTs. SAR 60 m.	No dead bats found
LEA (2010e), Penedo Ruivo, Portugal	2009	Ridge SW-NE, range altitude 1120-1220m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and pine stand	10 WTs	as above	No dead bats found

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
LEA (2010e), Seixinhos, Portugal	2009	Ridge NE-SW, range altitude 1197-1260m; totally integrated in an important area for the conservation of the biodiversity; low bushes	8 WTs	as above	No dead bats found
LEA (2011), Sobrado, Portugal	March - October 2011	Mean alt. 1280m; shrubs	4 WTs (of 2,0 MW)	MM: weekly from March to October around all 4 WTs. AS: Presence/absence of bats, identification of the species detected, and the existence of feeding activity and social calls were detected. 10 min of census were done at each sampling point (N=12), with a BD (D240X, Pettersson Elektronik). The number of bat passages detected during each listening was registered. Species with vocalizations difficult to distinguish were associated in groups of two or more species.	AS: Rfer, Mesc, Ppip, Hsav, Nlei, Tten, Espp., Plspp. and Nspp./Espp. MM: No dead bats found.
LEA (2012a), Alto do Marco, Portugal	July 2011 - June 2012	Mean alt. 1250m; shrubs	6 WTs (of 2,0 MW)	MM: monthly from November to February and weekly searches from March to October around all 6 WTs. AS: as above, 12 sampling points.	AS: Rfer, Ppip, Ppyg, Pkuh, Hsav, Bbar, Tten, Espp., Pspp. and Nlei /Espp. MM: 8 dead bats found during study (3 Ppip; 2 Nlei; 1 Tten; 1 Hsav); MR: 6,35 /WTs/year.
LEA (2012b), Negrelo e Guilhado, Portugal	Mid March - mid October	Mean alt. 1100m; shrubs	10 WTs (of 2,0 MW)	MM: Weekly searches from 15 March to 15 October around all 10 WTs. AS: as above, 14 sampling points.	AS: Ppip, Pkuh, Hsav, Bbar, Tten, Mspp., Espp., Plspp. and Ppip/Ppyg. MM: 2 dead bats (1 Ppip; 1 Hsav); MR: 0,47/WTs/year.
LEA (2012c), Mafômedes. Portugal	March - October 2011	Mean alt. 1100m; shrubs	2 WTs (of 2,0 MW)	MM: monthly from November to February and twice per month from March to October around all 2 WTs. AS: as above, 3 sampling points.	AS: Ppip, Tten, Espp., Plspp., Ppip/Ppyg, Espp./Nlei. MM: no dead bats found
LEA (2012d), Penedo Ruivo e Seixinhos, Portugal	March - October 2011	Mean alt. 1270m; shrubs	18 WTs (of 1,8 MW)	MM: monthly from November to February and twice per month from March to October around all 18 WTs. AS: as above, 22 sampling points.	AS: Rhip, Mesc, Pkuh, Ppip, Hsav, Nlei, Bbar, Tten, Espp., Pspp., Ppip/Ppyg, Ppip/Msch/Ppyg, Nspp./Espp., Nlas/Nnoc/Espp. MM: no dead bats found
LEA (2013), Alto do Marco, Portugal	July 2012 - June 2013	Mean alt. 1250m; shrubs	6 WTs (of 2,0 MW)	MM: monthly from November to February and weekly from March to October around all 6 WTs. AS: as above, 12 sampling points.	
Lelong (2012), St Genou (Indre), France	6 months 2012	Cereal fields	6 x Vestas V80	MM: twice a week	MM: 2 Ppip, 1 Eser, 1 Pnat. MR 2012: 64/6WTs/6 months; correction for controler's efficiency, predation, surface
Long *et al.* (2009), UK			microturbines	Laboratory study with pipistrelle sounds	Ultrasound scattering properties of an operational WT increases with distance; blades may not be detectable to a bat at all at a distance greater than half a m, even when stationary
Lopes *et al.* (2008), Pinhal Interior (Proença I)	April - October 2006	Shrubs, pine	18 WTs	MM: weekly searches. SAR 46 m; SET (spring, summer, autumn).	5 dead bats: 3 Pspp., 1 Hsav, 1 N/i. MR 2,8/year (7 months period)
Lopes *et al.* (2009), Pinhal Interior (Moradal), Portugal	June - October 2007	Shrubs, pine	5 WTs	as above	No dead bats
Mãe d'Água (2007), Lameira, Portugal	2006 - 2007	Ridge S-N, mean altitude 1332m; totally integrated in an important area for the conservation of the biodiversity; shrubland	8 WTs	MM: Control of 15 among 15 days of all WTs, during two successive days. SAR 50 m.	MR 0,63/WT/year

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Minderman *et al.* (2012), Central Scotland and northern England, UK	May - September 2010 (67 nights)		microturbines in central Scotland (N = 7) and northern England (N = 13): 5 building mounted, 15 free standing (tower 6-18m, rotor ø 1.5-13m). 18 3-bladed models, two 2-bladed models.	AS: at each site over four successive days and nights (limited to three days and nights at two, and to two days and nights at one site due to access restrictions), and data collection was repeated once during the season at three of the twenty sites. Activity was compared between experimental treatments: turbines running or broken. Bat activity was automatically recorded using 2 AnaBat SD2 BDs (Titley Scientific; one 0-5 m and one 20-25 m from the turbine) during all nights of the observation period at each site (detector failure at 2 sites). Between 19 and 244 hours were sampled per site, during which time turbines were braked between 6 and 102 hours. Weather conditions and landscape features were recorded.	8221 bat passes across all 18 sites: 87.6% Pspp., 12.4% Mspp., Nnoc, Plaur. Bat activity was lower when turbines were running and this effect depended on WT proximity.
NOCTULA (2012a), Safra-Coentral (Serra da Lousã), Portugal	February 2011 - February 2012	Mixed deciduous forest and pine; pine forest; tall bushes and deciduous forest; pine forest and low bushes.	Ecotecnia: ECO74	MM: weekly between March and June 2012 near all WTs with SAR 60 m. The following data were registered for the carcasses: a) species, b) sex c) GPS point, d) the distance to the nearest turbine, e) presence of trauma, f) presence or evidence of predation h) digital photograph i) weather conditions. AS: three types of information were recorded: (a) the presence / absence of bats in a particular area, (b) identification of the species detected, (c) the existence of feeding activity (when detecting a series of pulses with a high repetition rate emitted by bats in the terminal phase of an attempt to capture prey). 10 min of censuses in each sampling point (for details see Amorim *et al.* 2012 above). Monitoring bat shelters: 83 in February, April, and July.	AS: Ppip/ Ppyg; Mmyo/Mbly; Pkuh; Ppip; Eser/Eisa; Nlei/ Eser/Eisa; Tten; small Mspp.; Nspp. Shelters: 8 Rhip, 9 adult and 3 young Plaur/Plaus, 34 adult and 6 young Reur, 1 Hsav, 1 Rfer. MM: no dead bats found.
NOCTULA (2012b), Sobrado (Serra de Montemuro), Portugal	March - June 2012	Low bushes; rocky outcrops.	Repower: MM82evo	See above (NOCTULA 2012a). MM between March and June 2012.	AS: Ppip/ Ppyg (2 passes); Pspp. (Ppip/Ppyg) MM: no dead bats found.
NOCTULA (2013), Testos II (Serra de Montemuro), Portugal	September 2011 - August 2012	MM: as above, around all 11 WTs. AS: Presence/absence of bats, identification of the species detected, during 10 min of census were done at each sampling points (N=15), with a BD (D240X,- Pettersson Elektronik). The number of bat passages detected during each listening was registered. Species with vocalizations difficult to distinguish were associated in groups of two or more species. Monitoring bat shelters: 5 shelters were found and iNspp.ted.	ENERCON: E-82	See above (NOCTULA 2012a). MM in September and October 2011 and between March and August 2012. Monitoring bat shelters: 34 in February, April, and July.	AS (passes): 1 Bbar, 42 Ppip/ Ppyg, 1 Mmyo/Mbly, 15 Pkuh, 41 Ppip, 54 Nlei/Eser/Eisa, 32 Tten, 3 small Mspp.; 1 Rfer.
Oikon Ltd. (2014), Njivice, Split-Dalmatia County, Croatia	March - October 2013	Dry pastures and shrubs	20 WTs, tower 76.9m; rotor ø 82m.	MM: searches twice/month for 2-3 successive days. Search area: 70 m around WT in the area of maximum visibility (plateaus, roads and slopes) due to the very poor visibility in high grass and shrubs. AS: monthly monitoring of bat activity using BD.	148 dead bats: 35 Hsav, 50 Pkuh, 3 Pnat, 1 Tten, 7 Vmur, 15 N/i, 22 Pspp., 15 Pspp./Hsav
Park *et al.* (2013), UK			microturbines	Policy review.	Recommendations for research

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Procesl (2009), Alto Minho, Portugal	April - October 2008	Mean alt. 1200m; shrubs; pine plantations; grasslands	75 WTs (of 2,0 MW)	MM: monthly searches around 70% of the WTs. SAR 50 m; SET.	9 dead bats (2 Nlei, 5 Ppip, 2 Pspp.): 7 in September, 2 in October; MR 1,92/WT/ 7 months
Procesl/Bio3 (2010), Alto Minho I (sub-WFs Picos, Alto do Corisco and Santo António), Portugal	April - October 2009	Mean alt. 1200m; shrubs; pine forest; plantations; grassland	75 WTs (of 2,0 MW)	MM: monthly around 70% of the WT´s. SAR 50 m; SET.	9 dead bats (3 Ppip, 1 Pkuh, 1 Ppyg, 1 Eser, 1 Nlas and 2 Pspp.): 2 in July, 3 in August and 4 in September). MR: 2,89/WT/7months (St. António) 1,45/WT/7months (Alto do Corisco) and 1,89/WT/7months (Picos)
Procesl (2012a), Serra de Alvaiázere, Portugal	January - December 2011	Mean altitude: 600 m;Schrubs	7 WTs (of 2,0 MW)	MM: weekly searches around all 7 WTs; SAR 50 m; SET.	AS: 8 Rfer, 3 Rmeh/Rhip, 2 Mesc, 2 Mmyo/Mbly, 5 Mspp., 14 Ppip, 30 Pkuh, 5 Ppyg/Msch, 4 Pkuh/Ppip, 7 Ppip/Ppyg/ Msch, 8 Nlei, 5 Nlas/Nnoc, 2 Nspp.,10 Nspp./Espp., 1 Eser/ Eisa, 1 Bbar, 1 Pspp., 6 Tten. Shelters (15 in hibernation period):112 Rfer, 3 Rhip, 13 Rspp., 19 Mmyo/Mbly, 9 Mmyo, 2 Mbly, 1 Mdau, 2500 Msch. MM: 12 dead bats (3 Nlei; 1 Tten; 1 Ppyg; 1 Pkuh; 1 Msch; 2 Pspp.; 3 N/i); 2 in April, 3 in May, 3 in August, 3 in September and 1 in November. MR: not available.
Procesl (2012b), Serra de Aire, Portugal	January - December 2011	Mean altitude: 300 m;Schrubs, olive culture, airfield	11 WTs (of 2,0 MW)	MM: as above, around all 11 WTs. AS: Presence/absence of bats, identification of the species detected, during 10 min of census were done at each sampling points (n=15), with a BD (D240X, Pettersson Elektronik). The number of bat passages detected during each listening was regis-tered. Species with vocalizations difficult to distinguish were associated in groups of two or more species. Moni-toring bat shelters: 5 shelters were found and inspected.	AS: 1 Rfer, 1 Rhip, 1 Rmeh/Reur, 1 Mspp., 31 Ppip, 16 Pkuh, 1 Pkuh/Ppip, 9 Ppip/Ppyg/Msch, 6 Ppyg/Msch, 1 Pspp., 2 Nlei, 2 Nlas/Nnoc, 1 Nspp., 1 Nspp./Espp., 4 Eser/Eisa, 2 Pspp. Shelters (5 in hibernation period): 18 Rfer, 2 Rhip, 26 Rspp., 300 Mmyo, 3 Mbly, 100 Msch. MM: 3 dead bats (1 Nlei; 2 Pspp.): 2 in April, 1 in September. MR: 11,3/WT/year
Procesl (2013a), Sabugal, Portugal	January - December 2012	Mean altitude: 850 m;schrubs; rock outcrops	48 WTs (of 2,0 MW)	MM: weekly (7 searches from June to July 2012; 5 searches from September to October 2012) around in average of 80% of the WTs. SAR 50 m; SET. Predation values based on blibliography. AS: as above (n=28). Monitoring bat shelters: 2 shelters were found and inspected.	AS: 1 Rfer, 1 Reur, 1 Mesc, 4 Mspp., 2 Ppip, 107 Pkuh, 14 Ppyg/ Msch, 41 Pkuh/Ppip, 52 Ppip/Ppyg, 23 Pspp., 3 Hsav, 16 Nlei, 3 Nlas/Nnoc, 4 Nspp., 8 Espp., 7 Pspp., 4 Bbar, 21 Tten. Shelters (2 in August): 710 Rfer with offspring; 500 Reur/ Rmeh with offspring; 1 Mema. MM: 6 dead bats - 3 Ppip, 1 Pspp., 2 Nlei, MR: 21,9/WT in 2012.
Procesl (2013b), Serra de Alvaiázere, Portugal	January - December 2012	Mean altitude: 600 m;Schrubs	7 WTs (of 2,0 MW)	MM: Weekly, around all 7 WTs; SAR 50 m; SET	AS: 1 Mesc, 1 Mspp., 4 Ppip, 9 Pkuh, 2 Ppyg/Msch, 1 Pkuh/ Ppip, 5 Ppip/Ppyg, 3 Ppyg, 1 Pspp., 3 Nlei, 1 Nlas/Nnoc, 2 Nspp., 4 Bbar, 4 Tten. Shelters (8 in hibernation period): 223 Rfer, 6 Rhip, 50 Rspp., 32 Mmyo/Mbly, 10 Mmyo, 1 Mdau, 2 Mspp., 1963 Msch, 1 N/i. MM: 0 dead bats, MR: 0.
Procesl (2013c), Lourinhã II, Portugal	August 2011 - July 2012	Mean altitude: 170 m;eucalypt plantation; vine; agriculture	9 WTs (of 2,0 MW)	MM: Weekly searches (6 searches from 28 September 2011 to 3 November 2011; 8 searches from 23 May 2012 to 13 July 2012) around all 9 WTs; SAR 50 m; SET. Predation values based on blibliography.	AS: 3 Mmyo/Mbly, 2 Mspp., 24 Ppip, 2 Ppyg/Msch, 28 Ppip/ Ppyg/Msch, 1 Nspp., 1 Nspp./Espp., 1 Eser/Eisa. Shelters (5 confirmed): 15 Rfer, 1 Mmyo/Mbly, 120 Msch. MM: 6 dead bats (1 Msch; 2 Pspp.; 3 N/i): 1 in May, 1 in June, 1 in Sep-tember and 3 in October. MR 10,91/WT/year (2011/2012).
Profico Ambiente (2007a), Outeiro, Portugal	Spring 2006	Ridge NE-SW, range altitude1186-1311m; totally integrated in an important area for the conservation of the biodiversity; low bushes	15 WTs	MM: control of 15 among 15 days of all WTs. SAR 60 m; SET.	MR 2,52 /WT
Profico Ambiente (2007b), Outeiro, Portugal	Summer 2006	As above	15 WTs	as above	MR 1,86 /WT
Profico Ambiente (2007c), Outeiro, Portugal	Autumn 2006	As above	15 WTs	as above	MR 1,60 /WT

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Profico Ambiente (2007d), Outeiro, Portugal	All seasons 2006	As above	15 WTs	as above	MR 5,98/WT/year
Profico Ambiente/Bio3 (2009), Guarda, Portugal	May - mid June 2008; end August - beginning October 2008	mean altitude 990m; shrubs and grasslands	4 WTs	MM: weekly. Search area: 50 m around WT; SET.	1 dead bat (Nlei), MR 0,67/WT/12weeks
Profico Ambiente/Bio3 (2010), Guarda, Portugal	May - mid June 2009; September - mid October 2009	As above	4 WTs	as above	No dead bats found
Report unavailable (2010), Loire Atlantique 1, France	4 months	Fields with hedgerows	5 WTs	MM: controls once a week	48 dead bats, mainly Pspp., MR 51,1/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Report unavailable (2010), Loire Atlantique 2, France	4 months	As above	3 WTs	as above	28 dead bats, Pspp., MR 54,1/WT/year (LPO estimator (André 2004) after Winkelman 1992))
Report unavailable (2011), Loire Atlantique 1, France	7 months	As above	5 WTs	as above	15 dead bats, Pspp., MR 8,3/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Report unavailable (2011), Loire Atlantique 2, France	7 months	As above	3 WTs	as above	25 dead bats, mainly Pspp., MR 23,9/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Report unavailable (2011), Morbihan 1, France		Very close to woodlands or in fields connected to woodlands by hedgerows	6 WTs	as above	13 dead bats, mainly Pspp., MR 9,87/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Report unavailable (2012), Morbihan 1, France	8 weeks	As above	6 WTs	as above	No dead bats found
Rochereau (2008), Vienne, France	15 weeks	Alt. 135-140 m, arable land	4 x Ecotecnia 80-1.6	as above	1 dead bat, MR 0,65/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Rochereau (2009), Vienne, France	33 weeks	As above	4 x Ecotecnia 80-1.6	as above	4 dead bats, MR 3,12/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Rochereau (2010), Vienne, France	33 weeks	As above	4 x Ecotecnia 80-1.6	as above	1 dead bat, MR 0,22/WT/year (LPO estimator (André 2004) after Winkelman 1992)
Santos *et al.* (2013), Portugal	2003 - 2011			This study combines species distribution modelling with mortality data and the ecological conditions at WFs located in Portugal. Predictive models were generated to determine areas of probable mortality and which environmental factors were promoting it. Mortality data for four bat species, Hsav, Nlei, Pkuh and Ppip, were used. These experienced the highest levels of fatalities at WFs in Portugal, comprising 290 of the 466 fatalities recorded from 2003 to 2011.	The mortality risk models showed robust performances. WFs sited at humid areas with mild temperatures, closer than 5 km to forested areas and within 600 m of steep slopes showed higher probabilities of mortality. High mortality risk areas also overlapped highly with the potential distribution of Nlei in Portugal, suggesting that populations of this species may be at high risk due to WF fatalities. Moreover, a large extent of the area predicted to be a hotspot for mortality (*i.e.* areas likely to confer high mortality risk for four species) overlaps with sites highly suitable for WF construction.
Seiche *et al.* (2008), Sachsen, Germany	15 May - 30 September 2006	Some WFs in agricultural areas at sea level, some on hills (max. alt. 800m)	145 WTs in 26 WFs	MM: twice per week (morning, 30 min per WT). Search area equal to diam of the rotor + 25% around the WT (except for areas with dense vegetation); SET. AS: acoustic and night vision monitoring at 11 WTs (Pettersson D240x and Laar TDM 07C).	114 dead bats found (59 Nnoc, 24 Pnat, 15 Ppip, 4 Vmur, 4 Eser, 3 Ppyg, 1Mmyo, 1Enil, 1 Nlei, 2 N/i; 63 % juvenile and 34% adult). More species found with AS.

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Silva *et al.* (2007), Chão Falcão I, Portugal	March - October 2006	shrubs, eucaliptus	15 WTs	MM: weekly. SAR 46 m; SET (spring, summer, autumn).	No dead bats found
Silva *et al.* (2008), Caramulo, Portugal	March - October 2007	shrubs, pine	45 WTs	as above	79 dead bats, 2 alive bats: 37 Ppip, 3 Ppip/Ppyg, 3 Pspp., 1 Ppip/Pkuh, 5 Ppyg, 9 Pkuh, 4 Hsav, 11 Nlei, 1 Nlas, 1 Eser, 6 N/i; MR 13,3 /WT/year (8 months period)
Strix (2006a), Alagoa de Cima, Portugal	February 2006	Oak and pine woodland	9 WTs	MM: monthly searches. SAR 50 m; SET.	No dead bats found
Strix (2006b), Portal da Freita, Portugal	Winter 2006	Elevation 1344 m - Shrub (Erica sp. and Chamaespartium tridentatum) and grassland	2 WTs	MM: weekly searches. SAR 50 m; SET.	No dead bats found
Strix (2006c), Portal da Freita, Portugal	Spring 2006	As above	2 WTs	as above	No dead bats found
Strix (2006d), Portal da Freita, Portugal	Summer 2006	As above	2 WTs	as above	1 dead bat (Nspp.). MR 0,5 /WT/3 months
Strix (2006e), Portal da Freita, Portugal	Autumn 2006	As above	2 WTs	as above	No dead bats found
Strix (2007a), Penedo Ruivo, Portugal	2006	Ridge SW-NE, range altitude 1120-1220 m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and pine stand	10 WTs	MM: mortality search, SET.	No dead bats found
Strix (2007a), Seixinhos, Portugal	2006	Ridge NE-SW, range altitude 1197-1260 m; totally integrated in an important area for the conservation of the biodiversity; low bushes	8 WTs	MM: mortality search, SET.	MR 0,5/WT/year (the mortality happened in summer)
Strix (2007b), Penedo Ruivo, Portugal	2007	See above for Penedo Ruivo	10 WTs	MM: SAR 60 m. Control of 15 among 15 days of all WTs.	No dead bats found
Strix (2007b), Seixinhos, Portugal	2007	See above for Seixinhos	8 WTs	as above	No dead bats found
Strix (2007c), Videira, Portugal	March - October 2006	Range elevation 507-522 m. shrub and grassland.	3 WTs	MM: monthly, SAR 60 m, SET.	No dead bats found
Strix (2007d), Alagoa de Cima, Portugal	Spring 2006	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2007e), Alagoa de Cima, Portugal	Summer 2006	Oak and Pine woodland	9 WTs	MM: monthly. SAR 50 m, SET	No dead bats found
Strix (2007f), Alagoa de Cima, Portugal	Autumn 2006	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2007g), Alagoa de Cima, Portugal	Winter 2007	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2007h), Seixinhos Portugal	2006	See above for Seixinhos	8 WTs	Efficiency, predation and controlled surface	MR 1,86 /WT/year
Strix (2008a) Videira, Portugal	March - October 2007	Range elevation 507-522 m. shrub and grassland.	3 WTs	MM: monthly. SAR 60 m, SET	No dead bats found
Strix (2008b), Alagoa de Cima, Portugal	Spring 2007	Oak and Pine woodland	9 WTs	MM: monthly. SAR 50 m, SET	No dead bats found

Study (author, year, area)	Time	Habitat types	Data on WTs	Methods	Results
Strix (2008c), Alagoa de Cima, Portugal	Summer 2007	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2008d), Alagoa de Cima, Portugal	Autumn 2007	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2008e), Alagoa de Cima, Portugal	Winter 2008	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2008f), Caravelas, Portugal	Winter 2006	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2008g), Caravelas, Portugal	Spring 2007	Oak and Pine woodland	9 WTs	as above	1 dead bat (Ppip), MR 0,11 /WT/3 months
Strix (2008h), Caravelas, Portugal	Summer 2007	Oak and Pine woodland	9 WTs	as above	No dead bats found
Strix (2009a), Mafômedes, Portugal	2008	Ridge NE-SW, range altitude 1075-1110m; totally integrated in an important area for the conservation of the biodiversity; low bushes, shrubland and pine stand	2 WTs	MM: monthly. SAR 60 m, SET	No dead bats found
Strix (2009a), Penedo Ruivo, Portugal	2008	see above for Penedo Ruivo	10 WTs	MM: Control of 15 among 15 days of all WTs, SAR 60 m.	No dead bats found
Strix (2009a), Seixinhos, Portugal	2008	see above for Seixinhos	8 WTs	as above	No dead bats found
Strix (2009b), Videira, Portugal	March - October 2008	Range elevation 507-522 m. shrub and grassland.	3 WTs	MM: monthly. SAR 60 m, SET.	No dead bats found
Traxler *et al.* (2004), Prellenkirchen (Pr), Obersdorf (Ob), Steinberg/Prinzendorf (St/Prinz), NÖ, Austria	September 2003 - September 2004	St/Prinz: Natura 2000 area March-Thaya-Auen 12 km east of WF. Agricultural area near oak and common hornbeam forest (also Natura 2000 area). Ob: Agricultural area, partly with hedges/ shelter belts and small pine forests. Pr: Agricultural area with hills and with the Danube and Hundsheimer Berge to the north. Partly vineyards, near a Natura 2000 area.	St/Prinz: 9 WTs, Vestas V80; 2.000 kW; tower 100m, rotor ø 80m. Ob: 5WTs, E-66 18.70, 1.800 kW, tower 98m, rotor ø 70m. Pr: 8WTs, E-66 18.70, 1.800 kW, tower 98m, rotor ø 70m.	MM: every day (morning) under 5 WTs (1 WT at Ob, 2 WTs at Pr, 2 WTs at St/Prinz). SAR 100m (vegetation kept short). Observation of (migrating) birds and bats within a circle of 500m diam around the WT for 15 min. Line transects (car and on foot); SET.	St/Prinz: 4 dead bats found (Pnat, Plaus, 2 Nnoc). No flying bats observed. Ob: No dead bats found. Few observations of single bats (Nnoc). Pr: 3 dead Nnoc found (outside observation period) and additional 10 dead Nnoc found. Autumn migration of Nnoc was observed on several days (3.14 / hour in WF, 8,73 /hour in control area). Bats did not show avoidance behaviour toward the WTs. Other area - Deutsch Haslau: 1 dead Nnoc found. Calculated collision rate for all 3 parks: 5.33/WT/year.
Trille *et al.* (2008), Castelnau-Pegayrols, Aveyron, France	2008 (LPO12)	Pastures, hay meadows, cultures, along coniferous forest	13 WTs x 2500 kW	MM: 2008: 09/06-01/07 no protocole, 03/07-19/10 with SET.	MM 2008: 73 bats (49 Ppip, 6 Pkuh, 13 Pspp., 2 Eser, 1 Nlei, 2 N/i) No estimation of MR.
Zagmajster *et al.* (2007), Ravne, Pag Island, Southern Kvarner and Trtar Krtolin, Šibenik, Northern Dalmatia. Croatia	Ravne: 28 April, 01 May, 29 July 2007; Trtar Krtolin: 01 November 2006	Ravne: Middle of the island, alt. 200m. Trtar Krtolin: on a plateau, alt. 400m.	Ravne: 7WTs, tower 49m, rotor ø 52m. Trtar Krtolin: 14 WTs, tower 50m, rotor ø 48m.	MM: control in the morning.	6 dead bats found (Ravne: 2 Hsav, 4 Pkuh. Trtar Krtolin:1 Hsav).
Zieliński *et al.* (2011), Gnieżdżewo gm. Puck, Poland	15 March - 15 November 2011	Agricultural area, close to a town.	11 WTs	MM: control, also with trained hunting dog (high graminеous vegetation under most WTs). SAR 70m. SET of the dog.	6 dead bats found during study (3 Pnat, 1Enil, 1 Vmur, 1N/i). 17 dead bats found in the years 2007-2011 (8 Pnat, 2 Vmur, 1 Enil, 1 Ppip, 1Ppip/Ppyg, 1 Ppyg, 3 N/i).

List of abbreviations:

AS = activity survey
Bbar = *Barbastella barbastellus*, European barbastelle
BD = bat detector
Eisa = *Eptesicus isabellinus*, Isabelline Serotine
Enil = *Eptesicus nilssonii*, Northern bat
Eser = *Eptesicus serotinus*, Common serotine
Espp. = *Eptesicus* species
Hsav = *Hypsugo savii*, Savi's pipistrelle
Mbec = *Myotis bechsteinii*, Bechstein's bat
Mbly = *Myotis blythii*, Lesser mouse-eared bat
Mbra = *Myotis brandtii*, Brandt's bat
Mdas = *Myotis dasycneme*, Pond bat
Mdau = *Myotis daubentonii*, Daubenton's bat
Mema = *Myotis emarginatus,* Geoffrey's bat
Mesc = *Myotis escalerai*, Escalera's bat
MM = mortality monitoring
Mmyo = *Myotis myotis*, Greater mouse-eared bat
Mmys = *Myotis mystacinus*, whiskered bat
Mnat = *Myotis nattereri*, Natterer's bat
MR = mortality rate
Msch = *Miniopterus schreibersii*, Schreibers' bat
Mspp. = *Myotis* species
N/i = species wasn't identified
Nlas = *Nyctalus lasiopterus*, Greater noctule
Nlei = *Nyctalus leisleri*, Leisler's bat
Nnoc = *Nyctalus noctula*, Noctule bat
Nspp. = *Nyctalus* species
Pkuh = *Pipistrellus kuhlii*, Kuhl's pipistrelle
Plaur = *Plecotus auritus*, Brown long-eared bat
Plaus = *Plecotus austriacus*, Grey long-eared bat
Plspp. = *Plecotus* species
Pnat = *Pipistrellus nathusii*, Nathusius' pipistrelle
Ppip = *Pipistrellus pipistrellus*, Common pipistrelle
Ppyg = *Pipistrellus pygmaeus*, Soprano pipistrelle
Pspp. = *Pipistrellus* species
Reur = *Rhinolophus euryale*, Mediterranean horseshoe bat
Rfer = *Rhinolophus ferrumequinum*, Greater horseshoe bat
Rhip = *Rhinolophus hipposideros*, Lesser horseshoe bat
Rmeh = *Rhinolophus mehelyi*, Mehely's horseshoe bat
Rspp. = *Rhinolophus* species
SAR = search area's radius around WT
SET = tests for search efficiency & predation
Tten = *Tadarida teniotis*, European free-tailed bat
WF = wind farm
WT = wind turbine
Vmur = *Vespertilio murinus*, Parti-colored bat

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Annex 2: Reported bat fatalities in Europe (2003-2014) - State 17/09/2014

Species	AT	BE	CH	CR	CZ	DE	ES	EE	FI	FR	GR	IT	LV	NL	NO	PT	PL	RO	SE	UK	Total
Nyctalus noctula	24				3	716	1			12	10					1	5	5	1		778
Nyctalus lasiopterus							21			6	1					8					36
Nyctalus leisleri			1		1	108	15			39	58	2				206					430
Nyctalus spec.							2									16					18
Eptesicus serotinus					7	43	2			14	1			1		0	3				71
Eptesicus isabellinus							117									1					118
Eptesicus serotinus / isabellinus							11									16					27
Eptesicus nilssonii						3		2	6				13		1		1		8		34
Vespertilio murinus				7	2	89				6	1		1				3	7	1		117
Myotis myotis						2	2			2											6
Myotis blythii							4														4
Myotis dasycneme						3															3
Myotis daubentonii						5										2					7
Myotis bechsteinii										1											1
Myotis emarginatus							1			1											2
Myotis brandtii						1															1
Myotis mystacinus						2					2										4
Myotis spec.						1	3														4
Pipistrellus pipistrellus		10		2	3	431	73			277		1		14		243	1	3	1		1059
Pipistrellus nathusii	2	3		3	2	565				87	34	2	23	7			12	12	5		757
Pipistrellus pygmaeus						46				121			1			31	1	2	1	1	204
Pipistrellus pipistrellus / pygmaeus			1				483			44	54					35	1	2			620
Pipistrellus kuhlii				62			44			81						37		4			228
Pipistrellus pipistrellus / kuhlii																19					19
Pipistrellus spec.				37	2	36	20			85	2		2			85		4		3	276
Hypsugo savii				53		1	44			30	28	10				43					209
Barbastella barbastellus						1	1			2											4
Plecotus austriacus	1					6															7
Plecotus auritus						5															5
Tadarida teniotis				2			23			1						22					48
Miniopterus schreibersii							2			4						3					9
Rhinolophus ferrumequinum							1														1
Rhinolophus mehelyi							1														1
Chiroptera spec.		1		14		46	320	1		175	8	1				102	2		30	7	707
Total	27	14	2	180	20	2110	1191	3	6	988	199	16	40	22	1	870	29	39	47	11	5815

AT = Austria, BE = Belgium, CH = Switzerland, CR = Croatia, CZ = Czech Rep., D = Germany, ES = Spain, EE = Estonia, FR = France, GR = Greece, IT = Italy, LV = Latvia, NL = Netherlands, NO = Norway, PT = Portugal, PL = Poland, RO = Romania, SE = Sweden, UK = United Kingdom

Annex 3: Maximum foraging distances of species and height of flight

In the framework of the Environmental Impact Assessment of wind farm projects, it is important to know the maximum distance at which the different species have been encountered while foraging and the height at which they can fly. The following table updates the information for the different bat species which have been killed by wind turbines. For most species the information comes from radio tracking studies (except data in blue) and the references cited are listed below the table. As the maximum distance can vary according to the individual status or the season, different values are indicated.

Species	Max foraging distance (km)	Height of flight (m)	References	Radio-tracking studies
Nyctalus noctula	26	10 to a few hundred	1, 7, 30, 65	Yes, no
Nyctalus leisleri	17	above canopy, >25, >40-50 (foraging & direct flight)	5, 6, 30, 32, 42, 45, 64, 65, 68	Yes, no
Nyctalus lasiopterus	90	1300 (telescope & radar)	2, 3, 4, 30	Yes
Pipistrellus nathusii	12	1-20 (foraging); 30-50 (migration), >25, foraging above canopy & >40-50 in direct flight	43, 45, 46, 47, 30, 64, 65, 68	Yes, no
Pipistrellus pygmaeus	1,7 (mean radius)	up to the rotor, occasionally >25, >40-50 in direct flight	20, 30, 64, 65, 68	Yes, no
Pipistrellus pipistrellus	5,1	up to the rotor, >25, >40-50 in direct flight	21, 61, 65, 68	No; chemiluminescent tags, no
Pipistrellus kuhlii	no information	1-10; up to a few hundred, >25	30, 64, 65	Yes, no
Hypsugo savii	?	>100	33, 37, 64, 65	No, no
Eptesicus serotinus	5-7,12	50 (up to the rotor), >25, forages above canopy, >40-50 in direct flight	13, 14, 15, 16, 30, 62, 64, 65, 68	Yes, no
Eptesicus isabellinus	?	?	?	?
Eptesicus nilssonii	4-5 (breeding period); >30 afterwards	> 50 (foraging & direct flight)	51, 52, 64, 65, 68, 72	Yes
Vespertilio murinus	6,2 ♀; 20,5 ♂	20-40, above canopy (foraging) & >40-50 (direct flight)	48, 49, 64, 65, 68	Yes, no
Myotis myotis	25	1-15 (direct flight in open sky in transit); >25; up to 40 (50) in direct flight	26, 27, 28, 29, 30, 64, 68	Yes, no
Myotis blythii	26	1-15	22, 23, 24, 25, 26, 30	Yes
Myotis punicus	mean 6, up to 16,5	< 2 (foraging), probably 100 commuting from ridge to ridge	69, 70, 71	Yes
Myotis emarginatus	12,5; 3	no information ?	17, 18, 30, 33, 36, 38, 39	Yes
Myotis bechsteinii	2,5	1-5 and in the canopy, sometimes above canopy (direct flight)	12, 30, 31, 38, 39, 68	Yes, no
Myotis dasycneme	34; 15 from nursery, > 25 (spring and autumn)	2-5 (up to the rotor)	53, 63, 66 ; 73	Yes
Myotis daubentonii	10 ♀; >15 ♂	1-5, forages up to the canopy & sometimes above in direct flight	57, 58, 68	Yes, no
Myotis brandtii	10	up to the canopy (foraging) & sometimes above in direct flight	49, 54, 55, 68	?, no
Myotis mystacinus	2,8	up to 15 in the canopy, up to canopy (foraging) & sometimes above in direct flight	55, 56, 68	Yes, no
Plecotus auritus	2,2-3,3	up to the canopy and above (foraging and direct flight)	59, 68	Yes, no
Plecotus austriacus	regularly up to 7, usually 1,5	exceptionally >25, up to the canopy and above (foraging and direct flight)	60, 64, 67, 68	Yes, no
Barbastella barbastellus	25	above canopy, >25, canopy and above (foraging and direct flight)	11, 12, 30, 34, 35, 64, 68, 71	Yes, no
Miniopterus schreibersii	30 to 40	2-5 (foraging) and open sky (transit), >25	8, 30, 41, 40, 64	Yes, no
Tadarida teniotis	>30 (Portugal), 100 (Switzerland)	10-300	44, 9, 10, 30	Yes

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Annex 4: Detectability coefficients to compare activity indices

The following table (after Barataud 2012) is an example of activity indices that can be used. Activity indices (usually the number of contacts per time unit) result generaly of preconstruction surveys and are required by wind energy promoters to evaluate the risks of their projects. But the number of bat contacts/hour can only be compared between species that have calls of similar intensity. The probability of contacting a species with a low intensity call (*e.g. R. hipposideros*) is smaller than a species with a very high intensity call (*e.g. Nyctalus* spp.). Range variations of a signal depend also on many parameters that make comparison even more difficult. To allow comparison, bats have therefore been sorted according to the increasing intensity of their sonar calls. A detectability coefficient, based on the maximum distance of detection, has been calculated for two different observer's locations (open habitat vs. woodland). Applying this coefficient to the number of contacts or indices per species will then allow comparing the activity between species or groups of species. For more details see Barataud 2012.

Open space			
Intensity levels of calls	Species	Distance of detection (m)	Detectability coefficient
Low	*R. hipposideros*	5	5.00
	R. ferr./eur./meh.	10	2.50
	M. emarginatus	10	2.50
	M. alcathoe	10	2.50
	M. mystacinus	10	2.50
	M. brandtii	10	2.50
	M. daubentonii	15	1.70
	M. nattereri	15	1.70
	M. bechsteinii	15	1.70
	B. barbastellus	15	1.70
Medium	*M. blythii*	20	1.20
	M. myotis	20	1.20
	P. pygmaeus	25	1.00
	P. pipistrellus	30	0.83
	P. kuhlii	30	0.83
	P. nathusii	30	0.83
	M. schreibersii	30	0.83
High	*H. savii*	40	0.71
	E. serotinus	40	0.71
	Plecotus spp.*	40*	0.71
Very high	*E. nilssonii*	50	0.50
	V. murinus	50	0.50
	N. leisleri	80	0.31
	N. noctula	100	0.25
	T. teniotis	150	0.17
	N. lasiopterus	150	0.17

Clutter (underwood)			
Intensity levels of calls	Species	Distance of detection (m)	Detectability coefficient
Low	*R. hipposideros*	5	5.00
	Plecotus spp.	5	5.00
	M. emarginatus	8	3.10
	M. nattereri	8	3.10
	R. ferr./eur./meh.	10	2.50
	M. alcathoe	10	2.50
	M. mystacinus	10	2.50
	M. brandtii	10	2.50
	M. daubentonii	10	2.50
	M. bechsteinii	10	2.50
	B. barbastellus	15	1.70
	M. blythii	15	1.70
	M. myotis	15	1.70
Medium	*P. pygmaeus*	20	1.20
	M. schreibersii	20	1.20
	P. pipistrellus	25	1.00
	P. kuhlii	25	1.00
	P. nathusii	25	1.00
High	*H. savii*	30	0.83
	E. serotinus	30	0.83
Very high	*E. nilssonii*	50	0.50
	V. murinus	50	0.50
	N. leisleri	80	0.31
	N. noctula	100	0.25
	T. teniotis	150	0.17
	N. lasiopterus	150	0.17

* Note for *Plecotus* spp.: some high intensity calls are sometimes emitted during commuting flight in the open space (ref. call DVD 3.93)

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