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Guidelines for consideration of bats in wind farm projects

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Wind turbines in the Black Forest, Germany.
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Foreword

Following the Resolution 4.7, approved at the 4th Session of the Meeting of Parties (Sofia, Bulgaria, 22–24 September 2003), the EUROBATS Advisory Committee was requested to assess the evidence of the impacts of wind turbines on bat populations and, if appropriate, to develop voluntary guidelines for assessing potential impacts on bats and for constructing wind turbines in accordance with 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).

At the 10th Meeting of the Advisory Committee (Bratislava, Slovak Republic, 25-27 April 2005), based on the report prepared by the IWG, the Meeting agreed that guidelines for assessing potential impacts of wind turbines on bats should be developed and the IWG should continue to work on that subject.

Guidelines were then adopted at the 5th Session of the Meeting of Parties (Ljubljana, Slovenia, 4–6 September 2006) as an Annex to Resolution 5.6 (see page 50). Since then, the guidelines have been updated (as requested in point 7 of the Resolution) by including some new data from recent literature.

The membership of the IWG changed over time. Since its establishment and the preparation of these guidelines, the IWG has included seven permanent members: Luísa Rodrigues (Convenor; Portugal), Lothar Bach (Germany), Marie-Jo Dubourg-Savage (SFEPM, France), Christine Harbusch (NABU, Germany), Tony Hutson (IUCN), Teodora Ivanova (Bulgaria) and Lauri Lutsar (ELF, Estonia). Laurent Biraschi (Luxembourg), Colin Catto (BCT, UK), Jane Goodwin (UK), Katie Parsons (BCT, UK), Linda Smith (UK) and Christine Rumble (UK) also participated in the IWG during this period. Recently, other members joined this group: Eeva-Maria Kyheröinen (Finland), Kaja Lotman (Estonia), Jean Smyth (UK) and Per Ole Syvertsen (Norway).

1 Introduction

Europe is faced with the need to tackle climate change and environmental pollution and to find sustainable methods to meet demands for generating power. This is set out in Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market. European countries' governments are also mindful of the need to reduce climate change for the long-term survival of migratory species. Some governments have made commitments to source power from renewable resources, *e.g.* the UK is committed to ensure that 10% of the country's electricity should be generated from renewable sources by 2010/11 with an aspiration to double this by 2020[1].

The commitment to low-emission energy generation leads to an increased promotion of alternative methods for the production of energy, *e.g.* using wind power. However, wind turbines may cause problems for some animal species. They can have negative impacts on bat populations as well as on their prey and habitats, such as:

- Damage, disturbance or destruction of foraging habitats and commuting corridors;
- Damage, disturbance or destruction of roosts;
- Increased collision risk for bats in flight;
- Disorientation of bats in flight through emission of ultrasound noise.

Wind turbines have been described as a problem for birds for many years (Reichenbach 2002, Phillips 1994, Winkelman 1989); discussion has been mainly about their negative effect through bird-strike, but also about the disruption caused by wind farms to some bird species during breeding and migration (Reichenbach 2002). Since the 1990s, parallel to the discussions and findings about birds, it has been assumed that bat species foraging in the open air could be similarly affected. In the mid-1990s wind energy concerned mainly coastal areas, and the problems about bats and wind energy were discussed for the first time in two papers published in 1999 (Bach *et al.* 1999, Rahmel *et al.* 1999 [Germany]). About the same time, in the US, Johnson *et al.* (2000) published bird-strike findings, showing that the number of dead bats found under wind turbines was sometimes higher than the number of dead birds. Meanwhile other reports have corroborated the findings of bat collisions with wind turbines (*e.g.* Dürr 2001, Trapp *et al.* 2002, Dürr & Bach 2004 [Germany], Ahlén 2002 [Sweden], and Alcalde 2003 [Spain]). Please see table 1 (pp. 40-47) for further details. Altogether 20 European bat species were found to suffer collision fatalities, and 21 bat species are considered to be potentially affected (see table 2 on page 48 for further details).

[1] "Securing the Future – The UK Sustainable Development Strategy" HM Government, March 2005. Available from http://www.sustainable-development.gov.uk/documents/publications/strategy/SecFut_complete.pdf

Guidelines for the development of wind turbines have been prepared in some countries, but there are few examples where bats are considered. There is a need to provide more instructive bat guidelines within the EUROBATS Agreement area. The primary purpose of these guidelines is to raise awareness amongst developers and planners of the need to consider bats and their roosts, migration routes and feeding areas when constructors are assessing applications to build wind turbines. These generic guidelines should also be of interest to local and national consenting authorities who are required to draw up strategic sustainable energy plans. Furthermore, it may be a useful checklist for local authorities to ensure that the possible presence of bats and the effects on bats are taken into account when considering planning applications.

Contracting Parties of the EUROBATS Agreement are committed to a common goal: the conservation of bats throughout Europe. Bats are protected species under the EU Habitats Directive and the Bern Convention. Most bat species commute or migrate regularly between their summer roosts and the sites for hibernation. Some bat species even migrate over hundreds of kilometres across regional and national boundaries. Where bat migration crosses borders, any Strategic Environmental Assessment of wind energy plans with the potential for cross-boundary impacts should seek international co-operation from other governments.

2 General aspects of the planning process

These guidelines are applicable to schemes in urban as well as rural areas, ranging in size from domestic to the commercial scale and may also be applied to wind turbines planned for the offshore area. The impact of placing small turbines on the site of properties and their effect on bat roosts should also be considered.

There is growing awareness of the issue of climate change and the role of renewable energy in combating it. Planning is usually organised at the local or regional level and each locality or region has its own spatial 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. It is reasonable to assume that, depending on the selected site, there may be very little impact on bats. However, where there is reasonable likelihood of bats being present and affected by the development, planning authorities should seek to ensure ecological surveys and assessments are carried out at appropriate times and by experienced personnel.

The need to consider possible impacts on bats as part of the development control process and to adapt policy and practices in light of experience of the placement of existing wind turbines is vital to ensure that bats are not faced with an unnecessary threat to their survival. Possible mitigation measures might include planning conditions requiring the shutting down of turbines at critical times of the year. For example, there are plans for some wind turbines in Germany to shut down for varying periods between August and October. The turbines will shut down either for the whole night or the first half of the night, and in late September / early October during the late afternoon.

Planning authorities can regulate the construction and operation of wind turbines by means of planning conditions and/or planning obligations. Planning conditions and obligations can apply to a range of issues including size, nature and location of the project. When assessing planning applications for wind turbines and when drawing up conditions or obligations, planners should be mindful of possible effects of wind turbines on bats in terms of disturbance, severance of foraging or migration routes, habitat loss or damage, and collision. Planners should also insist that impacts of the turbines are monitored.

The phases involved in producing energy using wind turbines may have an impact on bats to a greater or lesser extent:

2.1 Site selection phase

Developers should consider locating wind turbines away from narrow bat migration routes and concentrated feeding, breeding and roosting areas. Buffer zones could be created around nationally and regionally important roosts. The presence of habitats likely to be utilised by bats such as forests, wetland and hedgerow networks, and habitat features such as individual trees, water-bodies or water courses should be taken into account. Their presence will increase the likelihood that bats may forage in these areas. Very open habitats may be less important for foraging, although they may form commuting or migratory corridors. Information on habitats and places where wind turbines may have an impact would aid decision-making.

The following table shows the most important impacts related to the siting and functioning of wind turbines, and to what extent they effect either the local or migrating population. More details are found in 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.
Impacts related to operating the wind farm		
Impact	**Summer time**	**During migration**
Ultrasound emission.	Probably a limited impact.	Probably a limited impact.
Loss of hunting areas because the bats avoid the area.	Medium to high impact.	Probably a minor impact in spring, a medium to high impact in autumn and hibernation period.
Loss or shifting of flight corridors.	Medium impact.	Small impact.
Collision with rotors.	Small to high impact, depending on the species.	High to very high impact.

2.2 Construction phase

Construction phase activity should be planned for times of the day/year when bats are not active. This requires local knowledge about the bat species in the area and understanding of their annual life cycle. A typical year in the life of bats involves a period when they are active (April - October) and a period when they are usually less active or in hibernation (November - March). Timing will vary for each species according to geographical location, and also from one year to the next, depending on weather conditions. Behaviour of some species will also play a part, as some cold-tolerant bat species are much more active during winter than other less hardy ones. Construction activity should be clearly delineated in any plan to ensure operations are restricted to less sensitive times.

Permanent access roads and buildings related to the construction of the site should also 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 to bats.

2.3 Operation phase

Depending on the locality and level of impact, consideration should be given to the use of planning conditions to planning consents. These might restrict the operation of wind turbines at times of peak bat activity such as during the autumn migration period.

2.4 Decommissioning phase

Planners can include conditions and/or planning agreements to accompany planning permission 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 local planning authorities should consider the need to include conditions that are favourable to bats and their habitats.

3 Carrying out impact assessments

Several studies have shown that in the course of a year most dead bats are found in late summer and autumn (Alcalde 2003, Johnson *et al.* 2003) and frequently are migrating species (Ahlén 1997, Ahlén 2002, Johnson *et al.* 2003, Petersons 1990). Bats from local populations may also be affected (Arnett 2005, Brinkmann *et al.* 2006). Therefore an environmental impact assessment (EIA) needs to include both periods: summer and migration time. This is especially true because wind turbines are no longer just a coastal phenomenon: the modern high-performance turbines are also found inland and bat migration is not restricted to coasts. Wind turbines are preferentially built on hill-tops which have a higher exposure to the wind: such sites are often at the edge of, or even in, woodland. Wind farms on hill-tops may cause the same problems as in the plains (bat-strikes, disruption of migration routes and feeding areas). However, if built in forests, the negative effects can intensify – especially for local bat populations – as not only foraging habitats but also roosts can be destroyed when the site is cleared to build turbines and access roads, and by the placement of cables connecting to the power network. If wind turbines are sited right in the middle of forests, tree felling will be necessary to erect them. This will create new linear features which may attract more bats to forage in the direct vicinity of the wind turbine, and the risk of mortality will increase if the clearing is not wide enough. In this case the recommended minimum distance (200 m) to forest edges will be the only mitigation measure acceptable if the project is not abandoned.

The assessment methodology must take into account the summer as well as spring and autumn migration aspects in order to avoid or mitigate the impacts satisfactorily. It is recommended that planners (after consultation with bat experts) assess potential impacts on bats when considering applications for all proposed wind turbines (*e.g.* Ahlén 2002, Bach & Rahmel 2004, Behr & von Helversen 2005, Brinkmann *et al.* 2006, Dürr & Bach 2004, Endl *et al.* 2005, Hötker *et al.* 2004, Johnson & Strickland 2004).

The following section provides information on impact assessments that are not a statutory requirement. Developers will also need to undertake formal assessments to meet EIA requirements where appropriate. Where certain development is likely to have significant environmental effects on bats (*e.g.* effects on roosts, flight paths, feeding grounds and seasonal migrations), an environmental impact assessment will be required before a planning authority can take a decision on whether to grant planning permission.

3.1 Pre-survey assessment

The aim of the pre-survey assessment is to identify the species as well as the landscape features used by bats that are potentially at risk within the selected area. These results form the basis of an evaluation and conflict analysis, and for providing subsequent advice for avoiding, mitigating or adjusting the impacts. Given the impacts that wind turbines may have on bats, it is re-commended that a pre-survey assessment should be undertaken for all new inland and offshore wind turbine proposals. The pre-survey assessment is a preliminary step to gather evidence of any likely impact on bats that may be present to help the developer in his decision whether a more detailed survey is required.

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

Consideration should be given to include the following as part of the pre-survey assessment:

a) Collation and review of existing information

A range of information sources should be reviewed to help to identify potential habitats for bats and impacts that may arise from a proposed wind turbine.

These should include:

- Aerial photographs / maps / habitat survey maps;
- Species distribution maps;
- Records of known roosts and bat sightings. For offshore sites this should 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;
- European bat migration data.

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

- Local bat groups;
- Biological Records Centres;
- Wildlife Trusts;
- Statutory Nature Conservation Organisations;
- Bat Conservation Trusts;
- Natural History Museums;
- University research organisations;
- Provincial authorities;
- Consultants that have worked in the area.

b) Assess the likelihood of bats being present

In addition to the desk study it is recommended that a preliminary site survey be undertaken to identify/confirm potential features within the survey area that could be used by bats. The preliminary survey is likely to require a broad scale approach to identify the possible functions for each part of the survey area, for example for roosting, foraging and commuting. This part of the assessment should also consider potential migration routes.

c) Identify potential impacts

The existing information and the site survey should be used to decide if bats are known to be present, the number of species, which landscape features are good for bats (roost, foraging, corridors) and which impacts are likely or could potentially arise. For each wind turbine proposal, consideration should be given to how it may affect bats. In particular, wind turbines can potentially result in the following impacts:

- Death through collision with rotary blades;
- Disturbance or severance of migration routes;
- Disturbance or severance of local commuting routes;
- Disturbance or loss of foraging habitats;
- Disturbance or loss of roosts, although this is more likely to occur where turbines are located in woodland habitats or close to buildings.

d) Identify the scale of the assessment and future survey likely to be needed

When considering the potential effects of a proposed wind turbine, consideration should be given to local movements of bats to and from foraging sites, to long-distance movements between summer and hibernation sites and to autumnal swarming.

Migration routes over land and offshore should be considered. Particular consideration should be given to migration routes for wind turbine locations 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 flight lines between principal land masses and islands should also be taken into account, especially where there are records for bats on islands. It is recommended that for land based wind turbines the pre-survey assessment should consider bat activity within a 10 km radius of the wind turbine.

3.2 Survey

3.2.1 Survey design

Survey design will differ depending on the proposed location of the wind turbine. However, consideration should be given to the spatial scale of the survey, which should closely reflect the size and number of wind turbines, potential use of the site by bats and how this may affect the timing of survey work.

A wind park in the Black Forest in Germany. Local populations of pipistrelle bats (Pipistrellus pipistrellus) were affected by these wind turbines, as well as migrating species such as Leisler's bats (Nyctalus leisleri).
© H. Schauer-Weisshahn & R. Brinkmann

Larger wind turbine blades have a typical rotation zone of between 25 and 180 metres above the ground and therefore consideration should be given to the height at which survey work should take place. Such turbines are likely to affect high flying species, although it is recommended that all species are considered and assessed.

Given the potential impacts on bats it is unrealistic to present an accurate and complete EIA for a specific wind farm project without taking into account the possible presence of bats throughout a timescale which reflects the full cycle of bat activity. According to species and geographical situation in Europe this cycle of activity can vary from mid-February to mid-December. The intensity of survey work throughout this period may also vary depending on the location of the proposed wind turbine and the potential use of the site.

Although the timing of the survey is strongly dependent on weather conditions, it should not only provide a good picture of use for foraging and commuting purposes by local bat populations, but should also identify migration of bats. As a consequence it is recommended that a greater intensity of survey work should be undertaken in spring and autumn when bats are migrating. The timing of such surveys could be guided by consideration of records *e.g.* of when bats begin to leave their hibernation roosts, when maternity colonies disperse, or when mating takes place and swarming starts in the area.

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

3.2.2 Survey methods

3.2.2.1 Land-based wind turbines

Surveys of proposed wind turbine sites should imply the use of the best methods and equipment for the relevant habitat, *e.g.* hand held or automated bat detectors, radio tracking whenever necessary and also trapping (in forests or highly structured areas only). However, consideration should be given to the height at which surveys may need to be undertaken. These should reflect the proposed height of the wind turbines; therefore, the use of automated bat detectors from the ground and/or attached to kites or to helium balloons should be considered, in addition to undertaking standard hand-held detector surveys. Existing structures (towers, masts or lighthouses) at the studied site can be used to place automatic detection systems.

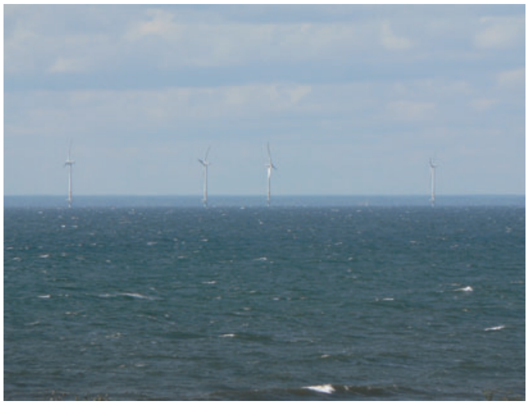
It has been suggested that the use of radar, sited along foraging, commuting or migration routes, in combination with bat detectors at different altitudes and night vision equipment (infrared or thermal cameras), could also provide data indicating the height at which bats are flying, but more tests are necessary to authenticate the results and prove the usefulness of this equipment. Radar is not a tool on its own but must be used with conventional methods.

It is recommended that intensive activity surveys should be undertaken within a 1 km radius of each proposed wind turbine throughout the survey period and that seasonal use of roosts be determined within a 10 km radius. To provide an indication of migration routes, an intensive survey of a 1 km radius around the proposed wind turbine site to identify an increase in migratory species should be undertaken in spring and late summer / early autumn.

Wind turbines should not, as a rule, be installed inside nor within a distance of 200 m of woodlands due to the risk that this type of siting implies for all bats. In the vicinity of woods the height issue should be highlighted. Special attention should be given to the bat activity above the canopy. Imaging cameras and kites/balloons with bat detectors will give an indication of height. Radar, if it proves to be operational, may be less useful here than in less cluttered habitats. The focus should be on high flying species as well as on all the species that forage above the canopy *e.g. Nyctalus* sp., *Vespertilio murinus, Eptesicus* sp., *Myotis bechsteinii, Myotis nattereri, Myotis myotis, Pipistrellus* sp., *Hypsugo savii* and *Barbastella barbastellus*.

3.2.2.2 Offshore wind turbines

Offshore wind turbines should be surveyed in the same manner as land-based turbines, but will require surveys to be undertaken from boats, lighthouses, *etc.* Offshore wind turbine surveys, however, should concentrate on migration routes rather than foraging areas. Surveys should be concentrated in spring (April/May) and autumn (August/September), unless bats found on nearby oil rigs, islands *etc.* indicate their presence at any other time of the year. A study at sea in Sweden should provide more information soon.



Offshore wind parks, here in Sweden, can have negative impacts on bats when positioned on traditional migration routes.
© L. Bach

3.2.3 Survey effort

Depending on the local geographical conditions and on the species hibernating in the region, the dates for the beginning and the end of the survey will vary, as hibernation is shorter in southern Europe than in northern parts of the continent. The survey can therefore take place between mid-February and the end of November (or even mid-December) but the effort will also vary. The survey effort should be tailored to the individual site and the potential impacts using local information.

Different stages of bat activity must be investigated (for dates see 3.2.4.1 d):

(i) Commuting between post-hibernation roosts;
(ii) Spring migration;
(iii) Activity of local populations, checking also for flight paths, foraging areas *etc.* and concentrating on high flying species;
(iv) Dispersion of colonies, 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 Inland survey

a) Search for new nurseries

Within, for example, a 5 km radius to help assessing the stages (iii) and (iv) (see above) of bat activity (May to August).

b) Ground surveys

- Bat detector surveys (manual and automatic from the ground) for all stages of bat activity to determine
  - an activity index for each habitat in the study area (1 km radius around the planned siting of the wind farm) and for each planned siting of wind turbines (activity index = number of bat contacts per hour). However, in the results the percentage of feeding buzzes should also be noted.
  - preferably the species or groups of species (see above).
- Infrared camera (or the more expensive thermal imaging camera whenever available).

c) Height surveys

- Automatic surveys with a bat detector on a balloon, kite, weather tower or any other suitable structure (for activity index and groups of species, at all stages of activity cycle).
- The effectiveness of a radar in combination with
  - automatic recording using ultrasonic microphones placed at predetermined heights on a line attached to a balloon or kite (in order to have a height reference) and/or
  - an infrared camera

  has still to be shown.

d) Timing of survey

Depending on the local geographical conditions and on the presence of species with a very short hibernation period, the stages (i) to (vi) should be investigated in the following periods:

- 15 Feb - 30 Mar[2] (stage i): once a week, first half of night for 2 hours starting half an hour before dusk;
- 15 Mar[3] - 15 May (stage ii): once a week, first half of night from sunset for 4 hours and include 1 whole night in May for stage iii;
- 1 Jun - 15 Jul (stage iii): four times, always a whole night;
- 1 - 31 Aug (stage iv): once a week, first half of night from sunset for 4 hours including 2 whole nights;
- 1 Sep - 31 Oct (stage v): once a week first half of night from sunset for 4 hours including 2 whole nights in September. During this stage one should also search for mating roosts and territories. At the end of September and October on the European continent, *Nyctalus noctula* has been noted in large numbers hunting in the afternoon from 5 to 100 m above the ground. Therefore the survey should start 3-4 hours before sunset where this behaviour of *Nyctalus noctula* is suspected.

[2] Applies mainly to southern Europe, for *Miniopterus schreibersii, Rhinolophus euryale* and *Myotis capaccinii*.

[3] If stage (i) was irrelevant in the area.

- 1 Nov -15 Dec[2] (stage vi): once a week (if climatic conditions are appropriate), first half of night for 2 hours starting half an hour before dusk.

It is necessary to take cost implications into consideration (*e.g.* use of heat imaging cameras, of hiring radar with its technician, cost of helium for the balloon *etc.*).

Standardisation of post-installation surveys and monitoring is important so that impacts from turbines in different countries can be compared. Guidelines for monitoring are found in chapter 4.

3.2.4.2 Offshore survey

For offshore wind farms it is more difficult to survey bat activity, particularly as methods have not been tried and tested. From experience and results in the Baltic area it may be possible to combine observations from land and sea. The survey should concentrate on the migration period.

a) Survey from land:

- From (pointed) land marks, thought to be localities where bats leave in the direction of the planned wind farm;
- Bat detector surveys (manual and automatic from the ground);
- Infrared or thermal imaging camera whenever available;
- Automatic surveys with a bat detector mounted on a kite, lighthouse or any other suitable structure (for activity index and groups of species).

b) Survey at sea:

- Boat transects in the area of the planned wind farm (might be possible to combine with nocturnal bird census);
- If possible from regular night ferries crossing between two landmark tips that are believed to be important for bat migration (*e.g.* Bornholm-Rügen in the Baltic Sea);
- Radar from a lighthouse in combination with boat transects to check the radar determination of bats.

c) Timing of survey:

From beginning of April until mid-May, and from beginning of August until mid-October (depending on the locality) at least twice a week.

3.2.5 Survey report and evaluation

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

- The species present in the geographical and administrative area and their status.
- The methods and equipment used and their limitations.
- Survey dates and weather conditions.
- The species identified during the survey and their deduced behaviour (passing through, foraging, swarming, migrating) as well as the date and hour of observation. These results could appear in tables where the different seasons in bat activity (post-hibernation transit or spring migration, period of birth and rearing of the young, dispersal and swarming, autumn migration) will be individualised to allow better comparison.
- The difference in activity according to different night phases.
- The difference in activity at different altitudes, if a balloon (or another technique) has been used. However caution should be used when comparing ground results and height results monitored by different types of bat detector (the range and

accuracy of detectors differ between systems and producers).
- The exact positioning on maps of every single contact, as well as the type of recording (hand-held bat detector, automatic recording boxes, on the ground, in the air *etc.*).

The evaluation will take account of the local and regional situations in terms of protection and conservation status, function and use of the described habitats, the different impacts due to siting or to functioning in relation to species present or potentially present (especially in open agricultural habitats).

A conflict analysis should then be presented for each use of the site by each proven species. Every wind turbine siting must be evaluated accordingly and proposals made to limit the impacts. The sequence of measures should be avoidance – mitigation – compensation. For more details about the report and the analysis see Rahmel *et al.* (2004).

3.3 Repowering

It will be necessary to combine a search for bat fatalities under the existing wind turbines and a bat activity survey which takes into account the location and height of the future turbines. The monitoring methods proposed in chapter 4 with a reduced number of survey nights in summer would be recommended. The search for bat fatalities will help to assess if there is a problem with collisions on the site.

Search for dead bats:
- Search radius if possible equal to the total height of the wind turbine and in any case no less than 50 m;
- Same methods as in “Monitoring”;
- Search under at least half of the existing wind turbines. This should be done every two to five days combined with a detector survey the preceding night.

For more details about repowering and the related problems for bats see also Hötker (2006).

4 Monitoring the impacts

Monitoring of wind farms will establish the impacts of wind turbines on different species and will help in the understanding of the problems involved. Only individual wind farms have been monitored to date and no study has been conducted regarding the cumulative effects of wind farms grouped in the same area. To assess the impacts of wind turbines on bats, studies should use standardised methods to produce comparable results. The aim of the present work is to suggest methods to achieve this goal and to try to find ways of reducing the impacts on bats.

The direct impact due to the functioning of wind farms is not yet fully understood as in most cases the cause of collisions is unknown. Different hypotheses have been proposed, such as:

- Air turbulence;
- Failure to recognise the danger (too short a series of echolocation calls by bat species or too high a velocity of the rotating blades);
- A higher concentration of insect prey around the nacelle, which entices bats to forage in this area.

Monitoring the impacts of wind farms on bats will only have a scientific value if it takes into account the initial state of bat populations in the area before installation. A so-called BACI (Before and After Construction Impacts) study is therefore necessary.

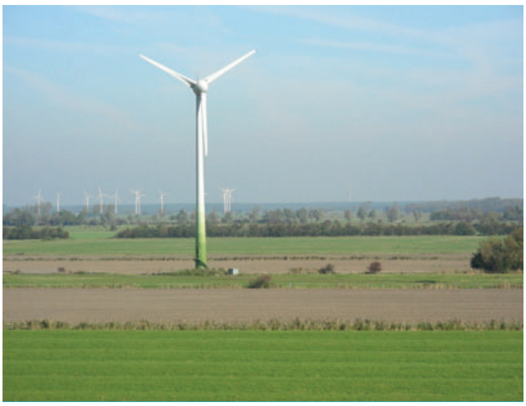
In order to avoid concluding that any change in bat activity pattern or behaviour is imputable to the wind farm when it can be due to yearly variations, one should also monitor a test zone in the vicinity of the wind park, with similar environmental characteristics (same types of habitats, same height of vegetation). No wind turbine should be built on this reference zone for the duration of monitoring.

A comprehensive monitoring scheme should focus on at least four research themes highlighted in the following section: loss of habitats, mortality, migration and behaviour.

4.1 Loss of habitats

To assess if the wind farm results in a loss of habitats for bats it is necessary to know:

a) Survey year 1: which species are present in the area before construction and which ones are foraging on the site or passing through during migration. A reference site (see above) should also be studied.



Wind park in Northern Germany. Foraging habitats of serotine bats (Eptesicus serotinus) and pipistrelles (Pipistrellus pipistrellus) are regularly found in this structured landscape. To avoid fatalities, a minimum distance of 200 m should be kept from such vegetation structures. © Lothar Bach

- Check the known roosts (but roost inventory in a 10 km radius if the wind farm has been built without any bat survey);
- Study of habitat use (with bat detectors on the ground and at different heights – infrared cameras optional).

b) Monitoring year 2: which species do not re-appear during construction (checking impacts on habitats and the disturbance the works bring to bats).

- Monitoring of the roosts;
- Continuation of the study of habitat use.

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, altogether 76 dead bats were found under the turbines, amongst them mainly noctules (Nyctalus noctula), Nathusius' bats (Pipistrellus nathusii), pipistrelles (Pipistrellus pipistrellus) and parti-coloured bats (Vespertilio murinus). © M. Lein

c) Monitoring year 3 to 5: during the functioning phase, impact assessment on resident species (attractiveness, changes in behaviour and mortality) and on migrating ones (behaviour and mortality): 3 years minimum and according to the results another 3 years, if necessary, for a new analysis. This can be achieved by checking with bat detectors which species are still present around the wind farm, if there is a noticeable decrease of activity index and a change of behaviour compared with the results of year 1 (Bach 2002).

- Bat detector monitoring at ground level (automatic and manual) and at different altitudes (balloons/zeppelins/kites/radar);
- Late afternoon visual observations and infrared cameras for behavioural assessment and migration;
- Bat mortality monitoring (see chapter 4.2).

4.2 Monitoring of mortality

The number of fatalities varies significantly according to the siting of the wind farm and the species to be found. The number of the findings is biased by predation and by the efficiency of the searcher (depending also on the type of ground cover underneath the turbines). Therefore the monitoring will consist of two stages:

4.2.1 Searching for bat fatalities

a) Search plot size

Ideally a radius equal to the total height of the wind turbine should be searched as bat bodies can be blown far away by high winds (Grünkorn *et al.* 2005). As in most cases this area cannot be searched properly due to the height of ground cover or to natural obstacles, it is advisable to search a smaller surface area that can be clear of vegetation all year round or at least covered with only very short vegetation. The radius should not be less than 50 m. The search area (squares are preferable to circles) will be marked out by 4 corner poles and two opposite sides with more poles indicating 10 or 5 m distance bands. The transects walked from one pole to the other will allow checking a band respectively 5 or 2.5 m wide on each side. If for some reason the area cannot be walked entirely, the percentage of the area searched should be calculated for each wind turbine.

b) Number of sampled wind turbines

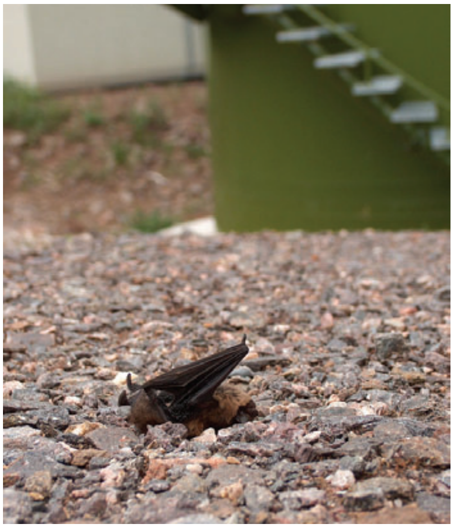
If possible, every wind turbine of the wind farm should be sampled. In the case of extensive farms, the turbines close to landscape features should automatically be checked and some others randomly selected. The number will depend on the size of the wind farm and its siting.

c) Time interval between samples

The smaller the time interval between samples, the higher the number of fatalities retrieved and therefore the smaller the bias of predation. An interval of 1 day between samples is suggested for small wind parks, with a 5-day interval (maximum) for larger wind farms (for comparison of results according to the time interval see Arnett 2005).

d) Monitoring schedule

Mortality monitoring should start as soon as bats become active after hibernation and last as long as they are not settled in their hibernaculum. But the schedule will vary according to the geographical and meteorological conditions. For example in southern Europe monitoring may start as soon as mid-February and finish as late as mid-December. As the highest numbers of dead bats have been recorded during migration periods, the search effort will be more intensive in spring and autumn:



Dead pipistrelle (Pipistrellus pipistrellus) hit by a wind turbine in forested area in Germany.
© H. Schauer-Weisshahn & R. Brinkmann

- 15 Feb – 31 Mar: 1 control/week or less;
- 1 Apr – 15 May: 1 control every 2 or 3 days
- 16 May – 31 Jul: 1 control/week;
- 1 Aug – 15 Oct: 1 control every 2 or 3 days;
- 16 Oct – 15 Dec: 1 control/week or less.

e) Search methods

The searcher should walk each transect at a slow and regular pace, looking for fatalities on both sides of the line. The search should start 1 hour after sunrise, when the lighting conditions enable dead bats to be distinguished.

The searcher should note the position of the carcass (GPS coordinates, direction to the wind turbine, distance to the tower), its state (fresh, a few days old, decayed, remnants *etc.*) with the type of wounds, the vegetation height where it was found (see below) *etc.* It will be necessary to record weather conditions in-between controls (temperature, wind – force and direction, thunderstorm) and the moon phases.

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

4.2.2 Estimation of mortality rate

A statistical analysis will be necessary to estimate the mortality rate on the wind farm monitored. This analysis will have to take biases into consideration (removal of carcasses by scavengers or predators, searcher efficiency).

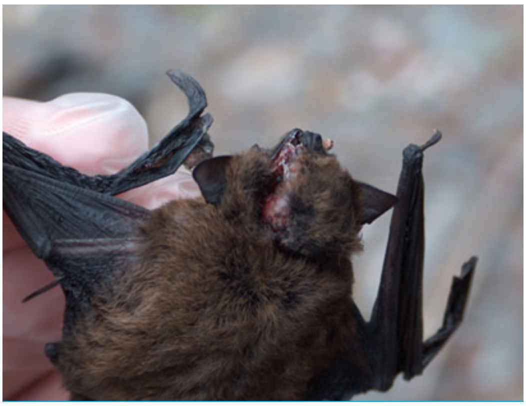
a) Carcass removal trials to estimate the predation rate

To estimate scavenging and predation, trials need to be done at least 4 times a year to take account of variable height of vegetation on the area searched. Bat flesh is probably less attractive to carnivores than bird flesh. Therefore, it is advisable to use frozen bat bodies if they are available (they will be thawed before use). However, in most cases trials will have to be performed with small passerines or one-day old chicks (preferably dark).

Each trial will last 10 consecutive days to determine how long a carcass stays on the ground before being eaten, removed or buried by mammals, birds and insects.

b) Searcher efficiency trials

- Classification of ground cover:
  As the searcher efficiency depends on the ground cover (height of vegetation and type of habitat affecting visibility, and season), it is important to determine detectability classes for fatalities. They will combine height and percentage of ground cover and of habitat features (type of vegetation, obstacles on the ground, slope) - for details see *e.g.* Habitat Mapping p. 26 & 28 in Arnett 2005 or Brinkmann *et al.* 2006. These classes are important for the statistical analysis.
- Trials:
  The searcher efficiency should be tested with different heights of vegetation (4 times a year).
  Bat bodies should be distributed at random on the search area of some turbines, the coordinates of each location having been noted (as well as direction and distance to the mast and the type and height of vegetation of each spot).
  The searcher should proceed as for a normal carcass recovery.
- Use of trained dogs:
  A dog trained to point at bats might be used for searching for victims but its efficiency should also be tested the same way as above. A pointer dog must be preferred to a retriever, so that his master



A pipistrelle bat (Pipistrellus pipistrellus) found dead with broken skull under a wind turbine (Germany). Also species usually known as low flying are found as casualties under wind turbines.
© H. Schauer-Weisshahn & R. Brinkmann

will be able to locate and register precisely the spot where the victim has fallen.

4.3 Migration

Large river valleys are usually used by most species in migration and special attention must be given to migratory species around wind farms situated in these valleys or on the nearby plateaux or ridges. The same should be done along coastlines.

Visual observations should start mid-afternoon, looking especially for *Nyctalus* species, and continue all night long with bat detectors (time expansion or frequency division on the ground combined with automatic time expansion, heterodyne or frequency division recording at different altitudes).

The study of migration needs to take into account bats passing through at altitudes out of range of the bat detectors on the ground. This can only be achieved with balloons, radar and/or infrared cameras (preferably thermal imaging cameras). However, the cost of running radar and cameras may limit the use of this equipment to large wind farms, problematic sitings or fundamental research.

A helium balloon (airship type zeppelin) with automatic recording of ultrasounds (via bat boxes) has been tested in France by the Museum of Natural History in Bourges and used successfully in France (Sattler & Bontadina 2006) and in Belgium. This equipment shows that bat activity is different in mid-air and close to the ground. Comparison of the activity index at different hours of the night can show a sudden increase in bat contacts which may indicate migration.

The French 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 (Pipistrellus nathusii), noctules (Nyctalus noctula) and common pipistrelles (Pipistrellus pipistrellus).
© F. Signoret/LPO

4.4 Behaviour

Except at dusk and dawn when visual observations of bats can be made, the study of bat behaviour relies upon expensive technologies such as infrared cameras, either thermal imaging or with a powerful illuminator. Due to its cost, the use of this equipment is limited to either problematic sitings or for fundamental research. However, with a hand-held bat detector it is possible to get hints of bat behaviour and at least to separate foraging from passing.

5 Research priorities

Our knowledge of the impact of wind turbines and wind farms on the environment and particularly bats is limited at present and there is a need for further research. Investigations so far confirm the large influence that wind farms may have on bats through collision and loss of hunting habitat. Further research projects are needed to increase our understanding on the impact of wind farms on bats either at an individual or population level. Compared to birds, the general knowledge about bat biology is rather selective and little is known about the bat migration routes throughout Europe. This information is the key to evaluating the risks in the planning of new wind farm projects. Furthermore, research projects should assess the risk of existing wind farms for bats. There is an urgent need to find solutions that will minimise their impact which can then be applied to the planning of future wind farms.

Several recent European and American studies have identified research needs which fall into six categories:

- Methodology development;
- Mortality and potential effects on bat populations;
- Migration;
- Collision;
- Disturbance, barrier effect;
- Mitigation and/or avoidance.

The following section (5.1 to 5.6) outlines the research needs *(priorities are marked in italics)* and mentions also possible investigation methods.

5.1 Methodology development

Methods need to be developed to observe and measure around existing and operating wind farms:

- Bat migration;
- Bats at high altitudes;
- Species distribution on a broad level (pre-survey phase).

Research needs	Possible methods
• *Further development and testing of existing methods (such as from Arnett 2005, Grünkorn et al. 2005, Traxler et al. 2004 for collision mortality studies), as well as novel techniques for measuring the impacts of wind farms, for example how to monitor bat collision rates or long-term effects such as the possible reduction of biological fitness of animals due to the loss of hunting habitat.*	• Technique used by Arnett (2005) (to provide pan-continental comparability); • Construction of a statistically robust model for collision mortality that can be universally applied to ensure comparability.

• Establish adequate census methods for bat activity at different altitudes.	• Thermal imaging camera; • Radar; • Detector/multi microphone arrays; • Bat activity registration systems; • At ground level and high altitude.
• Develop and test methods to investigate bat activity and collision rates at offshore wind farms.	• Radar; • Boat tours; • Automatic bat registration box.
• Develop and test methods to investigate bat migration over land and sea.	• Radio tracking; • Radar; • Ringing[4]; • Broad-scale, repeated and synchronised bat detector samples.
• Develop and test method models of geographical and ecologically relevant species distribution maps. These highlight the most important foraging areas across a large geographical range and act in a graduated fashion (most to least important) (*e.g.* Jaberg & Guisan 2001).	• GIS and habitat suitability models (*e.g.* Ecological Niche Factor Analysis).

5.2 Mortality and potential effects on bat populations

Further information is needed on:
- Whether bat mortality occurs at all sites or whether there are differences between sites;
- What factors from bat ecology and behaviour as well as from wind farm and individual wind turbine characteristics are affecting bat mortality;
- Whether it is possible to use information on landscape characteristics to avoid or mitigate problems;
- Whether mortality affects bats at the population 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.

Research needs	Possible methods
• *Potential population level impacts of bat collision mortality (which are completely unknown).*[5]	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Brinkmann *et al.* 2006, Grünkorn *et al.* 2005); • Genetic studies; • Population studies; • Population models.
• *The investigation of collision rates of bats per year and for different bat species with respect to different wind farm localities should be given a high priority. Systematic studies 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 are needed.*	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Grünkorn *et al.* 2005).
• At what times of the year do bat collisions occur? Several studies in the USA show a concentration of collisions in late summer / beginning of autumn. Data from Europe seems to support this, but several recent studies have concentrated on late summer and the beginning of autumn, so that statistical data about the seasonal distribution from several different localities are not available.	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Grünkorn *et al.* 2005).
• There is a total absence of quantitative data on the cumulative effects of onshore and offshore wind farms on migrating bats.	

[5] 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. → This kind of research should be set up in a broader sense.

A wind farm in the Rhône delta (Camargue, southern France). 21 windmills were built on an embankment in 2005. In 2006, 12 dead bats were found, among them Schreiber's bent-winged bats (Miniopterus 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

5.3 Migration

Further information is needed on:

- Where and when seasonal migration takes place;
- Whether flyways / migration zones exist and are recognisable;
- If so, what is their relation to landscape on a greater and smaller landscape scale;
- Whether it is possible to use information on peak migration activity and migration flyways in the landscape to avoid problems.

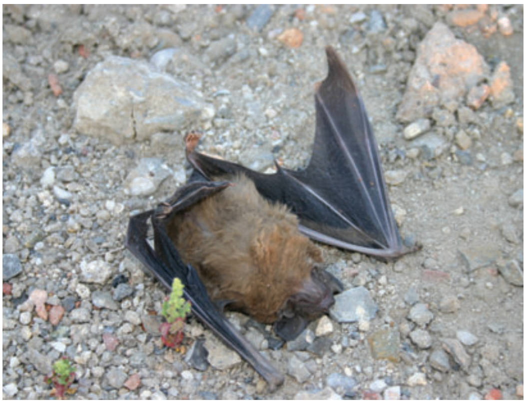
Research needs	Possible methods
• *Identifying migration routes / corridors and stepping stones. There are several studies on bat migration in different isolated places of Europe, but a continuous map of migration routes or stepping stones is not available. Although some studies and unsystematic observations do show that bats cross the open sea such as the North and Baltic Seas (Ahlén 1997, Ahlén et al. 2002, 2007, Russ et al. 2001, 2003, Walter et al. 2004, Hüppop pers. comm.), specific information on the exact offshore migration paths is not available.* • *Do landscape structures (river valleys, coastal lines, valleys between mountain ridges etc.) guide migration?*	• Bat ringing projects along migration routes; • Mist netting along migration routes; • International genetic studies (see Petit & Mayer 2000); • Radio-tracking; • Radar studies; • Detector studies on selected migration points.

• It is necessary to prove any anecdotal information and to understand that stepping stones are important, *e.g.* forests during spring and autumn for *N. noctula* and *P. nathusii*.	
• *It is not known under which weather conditions migration takes place onshore/inland and offshore. In general, wind (and visibility) will change behaviour and routes. Only a few examples exist concerning the different weather conditions in which bats are able to migrate.* ARNETT *(2005) and* BEHR *&* VON HELVERSEN *(2005) describe the main activity at wind speed < 6 m/sec. but many collisions occur at > 6 m/sec. From the morphology of Nyctalus and Miniopterus it is likely that they are also able to migrate in higher wind speeds. More data is needed on bat migration, such as site-specific information of migration routes and the numbers of bats that use them; species-specific flight altitudes; how timing, routing and direction are influenced by weather conditions; and how often bats stop to rest or forage.*	• Detector studies from ground, towers, wind turbines, balloons *etc.*; • Thermal imaging camera studies; • Radar; • Physiological and behavioural studies.
• Study of the orientation of migrating bats.	• Physiological studies.
• 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, boat transects (hand-held, automatic bat registration systems); • Thermal imaging; • Radar.

5.4 Collision

Further information is needed on:

- Why bats collide with wind turbines;
- Whether it is impossible / too difficult for bats to observe the wind turbine and understand the hazard;
- Whether they could be attracted to wind turbines;
- Whether techniques can be developed to warn off bats.



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

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

Research needs	Possible methods
• *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? This knowledge could be used to find ways of making blades more noticeable to bats.*	• Behavioural studies with detectors and thermal imaging cameras; • Laboratory experiments; • Echolocation experiments; • Physiological and behavioural studies.
• Recent studies from Germany (*e.g.* Behr & von Helversen 2005) indicate that not only migrating bats, but also foraging bats from the local populations collide with turbines. Migrating bats may also take the chance to forage during migration (*e.g.* Arnett 2005, Ahlén *et al.* 2007). Little genetic data on migrating and local bats is available to compare with data on bat fatalities.	• Genetic studies; • Thermal imaging camera and detector; • Radio tracking; • Insect studies at the wind turbine.

5.5 Disturbance, barrier effect

Further information is needed on:

- Behavioural responses of foraging local bats;
- Whether bats avoid wind turbines or habituate after a while;
- Whether habituation results in bat collision.

Research needs	Possible methods
• How foraging bats respond to wind turbines is not known. Adding to experience gained through collision studies we know that local serotine bats avoid foraging close to wind turbines (Bach 2002). We need to know more about the loss of hunting habitats of high flying bat species such as *Nyctalus, Vespertilio* or *Miniopterus* and the effect on their populations.	• Radio tracking; • Detector studies; • Habitat use studies; • BACI (before and after construction impacts) studies.
• Generic studies are needed on the behavioural responses of different species based on life cycle characteristics, population dynamics, ecology and abundance in response to construction, operational and removal phases of wind farms. This will establish species-specific sensitivities to several types of large-scale wind farms, *i.a.* identify the influence of turbine lighting on bat behaviour.	
• Influence of habitat availability on displacement.	• Radio tracking; • Detector studies.
• The effect that tower height has on foraging activity displacement needs attention. • Potential population level impacts on bats of displacement caused by disturbance, barriers to movement, collision mortality and habitat loss or damage.	• Habitat use; • Population studies; • Radio tracking; • Detector studies.
• The barrier effect on migrating and commuting bats is relatively unknown.	• Radio tracking; • Detector studies; • Study of behavioural response; • Population studies.
• Long-term studies are required to determine long-term effects of wind farms. Such effects could for example	• Ringing; • Population studies.

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 could be possible for local bats. Significant impacts on the population only become apparent in the long term.	

5.6 Mitigation and/or avoidance

Further information is needed on:

- The possibility of warning bats off;
- Techniques that could be developed to do this;
- The possibility of avoiding or mitigating problems.

Research project	**Possible methods**
• *Develop methods and instruments which can automatically record intensive hunting or high numbers of passing bats such as heat sensors and radar, which can feedback to and permit temporary shutting down of wind turbines during migration and inclement weather conditions.*	• Systematic collision mortality studies throughout the whole season (methods after Arnett 2005, Brinkmann *et al.* 2006, Niermann *et al.* 2007); • Automatic bat registration systems at high altitudes; • Thermal imaging camera.
• Are there any possibilities of deterring bats from wind turbines? Different kinds of noise/sound/radar signals and/or light signals should be investigated as possible deterrents or to ascertain whether such stimuli might actually attract bats. First studies have shown that some bats react negatively to strong radar (Nicholls & Racey 2007) but more detailed information about the technical requirements is still missing.	• Noise emission studies (infra-, normal-, ultrasound); • Radar studies.
• In some parts of Germany and Sweden it is known or suspected that bats roost inside nacelles. The nacelles should be closed to prevent bats from roosting inside. This is necessary to reduce the risk of injuries from cog wheels.	• Laboratory experiments; • Field observations.

6 Conclusions and further work

This paper 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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Glossary

BACI studies – Before and After Construction Impacts studies

Bern Convention – Convention on the Conservation of European Wildlife and Natural Habitats (1979)

EIA – Environmental Impact Assessment

EU Habitats Directive – Directive 92/43/EEC of the Council of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. The Habitats Directive (together with the Birds Directive) forms the cornerstone of Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection.

Nacelle (or: turbine nacelle) – The structure at the top of the monopole of the wind turbine to which the rotor hub and blades are attached; contains the electrical generator, gearbox and electronic controls.

Repowering – Replacement of first-generation wind turbines with modern multi-megawatt machines.

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Table 1: Studies done in Europe

Study (author, year, area)	Time	Type of turbines	Methods
Ahlén (2002, 2003), Sweden	August - September 2002	Different.	160 turbines (Gotland 66, Öland 39, Blekinge 4, Skåne 51); 1 control/turbine; Search area 50 m around turbine.
Alcalde (2003), Navarre, Spain and pers.com	1995 - 2003	Around 1,000 turbines; Height: 40 m (older model) and 60-80 m; Blade diameter: 20 m (older model) and 34 m.	Search area with radius equal to turbine height.
Bach (2002), Lower Saxony, Germany	April 1998 - September 2002	1 windfarm, 70 turbines; Height 45 m; Blade diameter 30 m.	Landscape use of Eser and Ppip; Systematic detector census in the whole park and the surroundings; 7 times/year; Start one year before the turbines were built until three years afterwards.
Benzal & Moreno (2001), Navarre, Spain		4 wind farms with turbines along 12.6 km.	
Behr *et al.* (2006), Ittenschwander Horn (Fröhnd), Germany	31 July - 30 October 2005	Site with 2 turbines; Nacelle height 85 m; Blade diameter 70 m.	Acoustic monitoring; Controls: 31/07-30/09: every second day, 01/10-30/10: every third day; Search area: 65 m; Estimation of search efficiency; Mouse experiment.
Behr *et al.* (2007), SW Germany	August - October 2004, July - October 2005	3 sites with 2 to 4 turbines; Total height 121-133 m; Blade diameter 70-77 m.	Acoustic monitoring at ground and nacelle level with automatic batcorders; 2-4 batcorders at each site, during 4 subsequent days in each month.
Behr & von Helversen (2005), Lahr, Germany	August - October 2004 and 26 July - 30 October 2005	Site with 3 turbines: Nacelle height 90 m; Blade diameter 77 m.	Acoustic monitoring; Controls every third day; Search area: 68 m.

Results	Habitat types
17 bats (Enil 8, Vmur 1, Nnoc 1, Pnat 5, Ppip 1, Ppyg 1); 0.1 bats/control; Gotland 12, Öland 2, Blekinge 2, Skåne 1; Distance 3-25 m (mean 12 m) around turbine; Half species are resident; Bats often feed close to blades; Species found dead are the ones observed hunting close to blades.	Different, from open with shrubs underneath to farmland (with hedgerows).
50 bats (mainly Hsav 25, Nnoc, Nlas 2, but also Ppip, Pkuh, Ppyg, Eser, Msch); Mainly August and September; Presence of turbines does not change habitat use; Number of flying bats increases with temperature and decreases with wind intensity; Bats use mainly areas close to trees.	Close to hedgerows.
No visible effect of the landscape use of Ppip; No visible negative effect of the use of flight paths of Eser and Ppip; Ppip changed the hunting behaviour close to the turbines and get used to the moving blades; The number of Eser that preferred to forage at hedges without turbines increased during the years; The number of Eser that hunted further away than 100 m to turbines increased during the years; After all: Eser seemed to leave the park after the turbines were built.	Farmland with many hedgerows 10-100 m from turbines.
Dead: Ppip, Pkuh, Hsav, Eser, Nnoc; Ppip, Pkuh, Hsav, Eser, Nnoc, Tten fly around turbines, although only a few hunt there; Bats use mainly areas close to trees.	
4 dead bats (Ppip 4); 0.18 bats/WT/night (16.5 bats/WT).	Forest.
Regular activity of 3 species: Ppip, Pnat, Nleis at both height levels. Only at ground level: Mnat, Mmysbra, Mmyo, Mbech, Mdaub, Plspec; Significantly more bats are active at low wind speeds (< 5 m/sec); Highest wind speed with bat activity: 6.5 m/sec; Local populations as well as migrating bats are concerned by WT.	Forested area (Black Forest), partially on sites cleared by storms (now shrubby growth).
3 dead bats (Ppip 3).	Forest.

Study (author, year, area)	Time	Type of turbines	Methods
Behr & von Helversen (2006), Rosskopf, Germany	End of April - mid of October	1 windfarm, 4 turbines; Height 98 m; Blade diameter 70 m.	2005: April-June every 3 days, July to October every 4 days; Estimation of search efficiency.
Brinkmann *et al.* (2006), Freiburg, Germany	2004: August - October; 2005: April - mid May and mid July - mid October	Different; 2004: 16 turbines, 69-98 m height, 44-80 m blade diameter; 2005: 8 turbines out of the 16 investigated in 2004.	2004: 9-18 controls/turbine; 2005: 12 spring controls / 18 autumn controls; Search area 50 m diameter around turbines; Estimation of search efficiency; Study with heat imaging camera.
Cosson (2004) and **Cosson & Dulac (2005, 2006 and 2007)**, France	IBA, SPA. Bird study first, then birds and bats. Mortality checked: 23 July - 16 December 2003; January - December 2004; January - December 2005; January - December 2006.	8 turbines N80; Height 100 m.	Control done for every turbine according to J.E. Winkelman's method.
Dürr (com. pers.), Brandenburg - Germany	2001 - 2003	Different types.	2001: 38 turbines (66 controls); 2002: 79 turbines (394 controls); 2003: 147 turbines (550 controls); ± unsystematically research between February and December, but mainly in August/September; Search area 50 m around turbine (mainly!)
Dürr (2007), Germany	1998 to 2007		List of all dead bats found by systematic or non-systematic search under WT in Germany, sorted by the German *Länder*.
Endl *et al.* (2005), Saxony, Germany	March - November 2004	16 wind farms, 92 turbines; Height 65-80 m; Blade diameter 47-80 m.	Detector census: 5-8 x / year (April - October); Collision control: 5-8 x / year (April - October) (mean 24-day-rhythm); Search area ~ blade diameter around turbine; Chicken experiment; Search efficiency control by bringing out paper bats!
Göttsche & Göbel (2007), Schleswig-Holstein, Germany	2003; July - mid September 2005; End of April - beginning of June 2006	Site with 4 turbines; Nacelle height 60 m; Blade diameter 80 m.	2003: non-systematic search for dead bats; July + September 2005 and April-June 2006: every 7th day; August 2005: every 14th day.

Results	Habitat types
2005: 31 bats dead (Ppip 23, Nlei 4, Pspec 4) =0.18 bat/turbine/night; April to mid-July: 11 bats; mid-July to mid-October: 20 bats; After curtailment of functioning period, the number of dead bats decreased significantly.	Forest in areas with trees blown down.
2004: 35 dead bats (+ 5 bats at an additional site investigated, Ppip 31, Nlei 7, Vmur 1, Eser 1); 2005: 10 dead bats (Vmur 1, Ppip 8, Nlei 1), no dead bats in spring.	Mostly forest, some at forest edges and meadows.
77 dead bats (2003-2006) (Pnat 35, Ppip 15, Pspec 17, Pkuh 2, Eser 2, Nnoc 6); 2003: M = 4.74 / week / 8 WT (6 months study); 2004: M = 3.1-3.6 / week / 8 WT (20.3-23.5 / year / WT); 2005: M = 3.30-4.19 / week / 8 WT (21.5-27.2 / year / WT); 2006: M = 0.93-1.43 / week / 8 WT (6-9.3 / year / WT) (in brackets: adjusted fatality estimates, the highest figures taking also into account adjustments for the searched area).	Open cultivated polder on one side and oyster beds on the other.
36 dead bats (0.04 bat/control); Mainly Pnat, Ppip, Nnoc; At all types of turbines; Mainly 1st and 2nd decade of August.	Different; Often close to hedgerows.
Altogether 706 dead bats found; Most affected species (in order of frequency): Nnoc, Ppip, Pnat, Nlei, Vmur, Eser, Ppyg; Of the bats determined, 45% were immatures and 55% adults; 52% of all bats were males; 91% of all finding were done between mid July to beginning of October; Discussion of research deficiencies.	Various types of habitats in Germany.
Mean mortality: 1.5 bats/turbine/year (range: 1.1-4.6); In 2 other wind farms: 1.34 and 4.56 bats/turbine/year; Ppip: higher collision rate close to forest; Nnoc + Pnat: collision also high far from forest.	Open farmland but mostly very close to forest or hedges (0-150 m).
22 dead bats found in total (Pnat 10, Ppip 5, Nnoc 4, Mdas 1, Mdau 1, Ppip/pyg 1), out of these 8 dead bats in 2005-2006 (Ppip 1, Pnat 4, Mdau 1, Nnoc 1, Mdas 1). Most dead bats found under the WT situated in open agricultural areas.	Different: open (3 turbines) to near hedges (1 turbines).

Study (author, year, area)	Time	Type of turbines	Methods
Grünkorn *et al.* (2005), Schleswig-Holstein, Germany	September - mid November 2004	3 wind farms, 24 turbines; Total height 100 m; 2 turbines total height 120 m.	Methodological study; 16 controls (every 5th day); Search area: turbine height; Experiments with birds of different size; Bird-fall experiments; Search efficiency control by bringing out dead birds of different size.
Grunwald & Schäfer (2007), Germany	July - October 2005 and July - October 2006	4 sites with 5 to 11 turbines each; Nacelle height 104-114 m; Blade diameter 70-90 m.	Acoustic monitoring at nacelle level with specially designed bat detectors and radio transmission of signals; Use of helium balloons.
Haase & Rose (2004)	March - April and August - October 2004	Height: 60 m, 70 m, 89 m; Blade diameter: 48 m; 58.5 m; 58.5 m.	3 controls/turbine/month; Bat activity per detector in the area around the turbines (ca. 500-1,000 m around the turbines).
Haensel (2007), Brandenburg, Germany	June - October 2006	Site with 1 turbine, but 12 others planned; Overall height of present turbines: 85 m, planned turbines: 149 m.	Detector study and non-systematic search for dead bats.
Kusenbach (2004), Thuringia, Germany	25 August - 23 September 2004	Different types (size mostly unknown!); 94 turbines (18 wind farms).	110 controls (1-3/turbine); Chicken experiment.
Latorre & Zueco (1998), Aragon, Spain			1 year
Lekuona (2001) and **Petri & Munilla (2002)**, Navarre, Spain	March 2000 - March 2001	10 wind farms, 400 turbines; Height: 40 m; Blade diameter: 40 m.	Bird study! 4 parks: 1 control/week March 2000 - March 2001; 1 parc: 1 control/week June 2000 - March 2001; Search area 50 m around turbine; many times only a small radius, due to vegetation.

Results	Habitat types
Need to search an area of the total turbine height; Area should be searched for small birds/bats in up and down transects 10 m wide; For small birds (bat size) (search area 10 m each site); Few vegetation cover (<10%): found rate 44%; High vegetation cover (>30%): found rate 8%; For small birds (bat size) (search area 5 m each site); High vegetation cover (>30%): found rate 10%; No dead bat was found.	Farmland, open area with few trees, bushes.
Species present at ground and nacelle height: Ppip, Nnoc, Nleis, Pnat; Species only present at ground level: Ppip, Ppyg, Mnat, Mmysbra, Mbech, Mmyo; Ppip and Nleis: flight activity at nacelle height correlated with structure richness: more activity in forests; More bats are active at low wind speeds (< 6 m/sec). Highest wind speed with bat activity: 8 m/sec (Nnoc).	
2 dead bats (Nleis 1, Plaurit 1); 0.06 bats/control; No observed activity of Nleis, Nnoc, and Ppip close to the turbines.	Farmland, 50-200 m close to hedgerows and forest.
Results of detector study: 10 species present (Mdaub, Mmysbra, Nnoc, Nleis, Eser, Vmur, Ppip, Ppyg, Pnat, Plspec); 2 dead bats found (Eser 1, Nnoc 1).	Very structured landscape with water bodies, hedgerows, large forests, rather extensive agriculture.
7 dead bats (Pnat 3 male/ad., Vmur 2 male/ad., Nnoc 1 female/juv., Chirop. spec. 1); 0.06 bats/control; 6 of 7 bats found in suspected bat migration corridor; Distance to wind turbine: 3-15 m; 1 bat with oily substance on the body; Chicken experiment: 30% recovered after 1 day; 15% recovered after 2 days.	20-100 m from hedgerows; Sometimes close to forest (3 x 200 m); Known bat migration corridors.
1998: 6 dead bats (Pspec 5; Tten 1); Estimation of number of dead bats: 274.05 bats/year; Estimation of number of dead bats: 10.15 bats/turbine/year.	
3 bats (Chirop. spec. 1, Ppip 1, Hsav 1) (2 in August, 1 in March); Disappearance rate: July - 57% in 24h and 70% in 48h; November - 67% in 24h and 80% in 48h; Average distance (cadavers): 25 m; Detection rate: July 13.2% and November 11.6%; Estimation of death rate in 2 farms: 3.09 and 13.36 bats/turbine; Estimation of number of deaths: 749 bats (using Winkelman´s index).	Different.

Study (author, year, area)	Time	Type of turbines	Methods
Schröder (1997), Lower Saxony, Germany	February + March 1997	47 turbines in different wind farms with different types of turbines.	Studying possible ultra sound of turbines with a bat detector (Pettersson D980); Checked frequency window: 14-100 kHz; Measurements distances: 20 m, 50 m, 100 m from turbines.
Seiche *et al.* (2007), Saxony, Germany	May - September 2006	26 sites with altogether 145 turbines.	Standardised search for dead bats (2-5 visits at each turbine per week); Detector monitoring; Night vision scope.
Trapp *et al.* (2002), Oberlausitz - Germany			
Traxler *et al.* (2004), Lower Austria	September 2003 - September 2004	3 wind farms: 4 turbines height 98 m, blade diameter 70 m; 2 turbines height 100 m, blade diameter 80 m.	6 turbines; 1 control/day/turbine; Search area 100 m around turbine; Search efficiency control by bringing out dead birds!
Zagmajster *et al.* (2007), Croatia	April - July 2007 and November 2007	First site with 7 turbines: nacelle height 49 m, blade diameter 52 m. Second site with 14 turbines: nacelle height 50 m, blade diameter 48 m.	Non-systematic search for dead bats.

List of abbreviations:

Enils = *Eptesicus nilssonii,* Northern bat
Eser = *Eptesicus serotinus*, Common serotine
Hsav = *Hypsugo savii*, Savi's pipistrelle
Mbech = *Myotis bechsteinii*, Bechstein's bat
Mdas = *Myotis dasycneme*, Pond bat
Mdaub = *Myotis daubentonii*, Daubenton's bat
Mmysbra = *Myotis mystacinus/brandtii*, Whiskered/Brandt's bat
Mnat = *Myotis nattereri*, Natterer's bat
Mschr = *Miniopterus schreibersii*, Schreibers' bat
Nlas = *Nyctalus lasiopterus*, Greater noctule
Nleis = *Nyctalus leisleri*, Leisler's bat
Nnoc = *Nyctalus noctula*, Noctule bat
Pspec = *Pipistrellus* species
Pkuh = *Pipistrellus kuhlii*, Kuhl's pipistrelle
Plaurit = *Plecotus auritus*, Brown long-eared bat
Plaus = *Plecotus austriacus*, Grey long-eared bat
Plspec = *Plecotus* species
Pnat = *Pipistrellus nathusii*, Nathusius' pipistrelle
Ppip = *Pipistrellus pipistrellus*, Common pipistrelle
Ppyg = *Pipistrellus pygmaeus*, Soprano pipistrelle
Tten = *Tadarida teniotis*, European free-tailed bat
Vmur = *Vespertilio murinus*, Parti-colored bat
Chirop. spec. = Chiroptera species

Results	Habitat types
12 x no ultrasound emission; 5 x few ultrasound emission; 13 x clearly ultrasound emission between 14-30 kHz; 13 types of turbines with clear ultrasound emission; but: The same turbine type with and without ultrasound emission.	
144 dead bats found; in order of frequency: Nnoc, Pnat, Ppip, Vmur, Eser, Ppyg, Mmyo, Enils, Nleis; Low mortality in May and June; 50% of death in mid-end of July; high mortality also from mid to end of August; 63% of dead bats are juveniles; Mortality different in the different natural regions of Saxony.	In lowland areas as well as in mountainous regions, open agricultural areas and structured landscapes - no forests.
34 bats (Vmur 6, Ppip 3, Pnat 10, Nnoc 12, Nleis 1, Chirop. spec. 2).	
14 dead bats (Nnoc 11, Pnat 2, Plaus 1); Collision rate (according Winkelman) mean 5.33 bats/turbine/year (Oberdorf: 0; Prellenkirchen 8.0; Steinberg 5.33 bats/turbine/year); Mean collision at wind speed 5-6 m/sec.; Highest collision rate in August; Bats hunting around moving blades in early afternoon.	Farmland, 50-200 m close to hedgerows and forest.
7 dead bats found (Pkuh 4, Hsav 3).	In lowland area on an Adriatic island as well as in mountainous region; structured landscapes.

Table 2: Bats' behaviour in relation to windfarms
Based on the knowledge and experience of IWG members and findings in literature.

Species	Hunting close to habitat structures	Migration or long distance movements	High flight (> 40 m)	Low flight	Max. distance (m) of ultrasonic detection (D980) (data from Michel Barataud)
Rh. ferrumequinum	X			X	10
Rhinolophus hipposideros	X			X	5
Rhinolophus euryale	X			X	5
Rhinolophus mehelyi					
Rhinolophus blasii					
Myotis myotis		X	X	X	30
Myotis blythii		X	X	X	?
Myotis punicus					?
Myotis daubentonii	X		X	X	30
Myotis emarginatus	X	?	X	X	15
Myotis nattereri	X			X	20
Myotis mystacinus	X			X	15
Myotis brandtii	X		X	X	
Myotis alcathoe	X			X	20
Myotis bechsteinii	X			X	25
Myotis dasycneme		X	X	X	
Myotis capaccinii				X	
Nyctalus noctula		X	X		100
Nyctalus leisleri		X	X		60-80
Nyctalus lasiopterus		?	X		100
Eptesicus nilssonii			X		
Eptesicus serotinus		?	X		50
Vespertilio murinus		X	X		
Pipistrellus pipistrellus	X		X	X	30
Pipistrellus pygmaeus	X	X	X	X	?
Pipistrellus kuhlii	X		X	X	30
Pipistrellus nathusii	X	X	X	X	30-40
Hypsugo savii	X		X	X	40-50
Plecotus auritus	X		X	X	30
Plecotus austriacus	X		X	X	30
Plecotus macrobullaris	?			X	30
Plecotus kolombatovici					
Barbastella barbastellus	X			X	30
Miniopterus schreibersii	?	X	X	X	30
Tadarida teniotis			X		150-200

Max. distance (m) of ultrasonic detection (D240) (data from Lothar Bach)	**Possibly disturbed by turbine ultrasounds**	**Attracted by light**	**Roosting inside nacelle**	**Known loss of hunting habitat**	**Risk of loss of hunting habitat**	**Known collision**	**Risk of collision**
20						X	X
							X
20-30						X	X
15							
20							X
20						X	X
15*							
30						X	X
150	X	X	?		X	X	X
	X	X	?		X	X	X
	?				X	X	X
50		X				X	X
50	X	X		(X)		X	X
50		X			X	X	X
30	?	X				X	X
30	?	X				X	X
	?	X				X	X
30-40	?	X				X	X
	?	X				X	X
10*						X	X
10*						X	X
20							
		X				X	X
	X	X				X	X

(* = during hunting)

EUROBATS.MoP5.Record.Annex9

5th Session of the Meeting of Parties

Ljubljana, Slovenia, 4 – 6 September 2006

Resolution 5.6

Wind Turbines and Bat Populations

The Meeting of the Parties to the Agreement on the Conservation of Populations of European Bats (hereafter "the Agreement"),

Noting the importance that wind energy has in the implementation of the Kyoto protocol to reduce CO_2 emissions in context of combating climate change;

Recalling Resolution 2.2 Consistent Monitoring Methodologies, which recommends the adoption of consistent monitoring methods for bats across Europe;

Recalling the Agreement's Conservation and Management Plan 2003-2006, which recognises the importance of international information exchange and cooperation in developing monitoring strategies for bats;

Recalling further the Agreement's Conservation and Management Plan 2003-2006, which recognises the conservation of bat habitats in all cases of land management and development especially when foraging areas or linear features directing to roosts are affected.

Noting the work of the Advisory Committee in producing Guidelines for the planning process and to assess the impacts of wind turbines on bats at a European level;

Recognising the importance of standardised methods to be able to find accurate mitigation and/or avoidance measures;

Recognising also the necessity of implementing research

Urges Parties and Range States to:

1. Raise awareness of the impacts that wind turbines might have on bat populations;

2. Raise awareness of the existence of some unsuitable habitats or sites for the construction of wind turbines at a local, regional and national scale;

3. Make developers of wind energy plants aware of the necessity of supporting research and monitoring;

4. Recognise the necessity to find suitable methods for assessing bat migration corridors;

5. Develop appropriate national guidelines, drawing on the current version of the generic guidelines in Annex 1.

Requests the Advisory Committee to:

6. Ensure, in cooperation with the Secretariat, the publication of the generic guidelines;

7. Keep the generic guidelines updated.

EUROBATS

Europe is faced with the need to tackle climate change and environmental pollution and to find sustainable methods to meet demands for generating power. 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 may on the other hand cause problems for some animal species such as bats. Therefore EUROBATS has developed guidelines for assessing potential impacts of wind turbines on bats and for constructing wind turbines in accordance with the ecological requirements of bat populations.

The primary purpose of these guidelines is to raise awareness amongst developers and planners of the need to consider bats and their roosts, their migration routes and feeding areas when constructors are assessing applications to build wind turbines. These generic guidelines should also be of interest to local and national consenting authorities who are required to draw up strategic sustainable energy plans. Furthermore, it is thought to be a useful checklist for local authorities to ensure that the possible presence of bats and the effects on bats are taken into account when considering planning applications.

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