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 Annex1.

Requests the Advisory Committee to:

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

7. keep the generic guidelines updated.

Annex1 to Resolution 5.6

Wind Turbines and Bats: Guidelines for the planning process and impact assessments

(Version 1.0, September 2006)

Authors

Luísa Rodrigues (Convenor; Portugal), Lothar Bach (Germany), Laurent Biraschi (Luxembourg), Marie-Jo Dubourg-Savage (SFEPM, France), Jane Goodwin (UK), Christine Harbusch (NABU, Germany), Tony Hutson (IUCN), Teodora Ivanova (Bulgaria), Lauri Lutsar (ELF, Estonia), Katie Parsons (BCT, UK)

on behalf of the Advisory Committee of the EUROBATS Agreement

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1. Introduction

Following the assessment of the evidence of the impact of wind turbines on bat populations, the EUROBATS Advisory Committee agreed that it would be appropriate to develop generic guidelines for the planning process and impact assessments to assist in determining where wind turbines can be best sited to reduce impacts on bats.

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, their migration routes and feeding areas when they are assessing applications for 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. It may also be useful checklist for local authorities to ensure that schemes have taken the possible presence of bats and the effects on bats into account, when considering planning applications.

Europe is faced with a need to tackle climate change and environmental pollution and to find sustainable methods to meet demands for the generation of power, accordingly to 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 have made commitments to source power from renewable resources, e.g. the UK Government 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].

Contracting Parties of the EUROBATS Agreement are committed towards a common goal: the conservation of bats throughout Europe. Contracting Parties are also mindful of the need to reduce climate change for the long-term survival of migratory species. Bats are protected species under the EU Habitats Directive and the Berne Convention. Bats are migratory species and regularly migrate between their summer roosts and the sites for hibernation. Some bat species also 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.

Wind turbines have been described as a problem for birds for many years (Reichenbach 2002, Phillips 1994, Winkelmann 1989): discussion is mainly about their negative effect through bird-strike, but also the avoidance of wind farms during breeding and migratory times by some bird species (Reichenbach 2002). Since the 1990s, parallel to the discussions and findings about birds, it has been assumed that bat species foraging in open air could similarly be 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 farms, both in Germany and abroad (e.g. Ahlén 2002 [Sweden], Alcalde 2003 [Spain] and Dürr 2001, Trapp *et al.* 2002, Dürr and Bach 2004 [Germany]). Please see Table 1 for further details. Altogether 19 European bats species were found to suffer collision fatalities, 21 bat species are considered to be potentially affected (Please see Table 2 for further details). Wind turbines may also have negative impacts on bat populations, as well as their prey and habitats, such as:

[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

- 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

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 side 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 scale 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 of the 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 a planning obligation. 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 they draw up conditions or obligations, planners should be mindful of possible effects of wind turbines on bats in terms of disturbance, severance of foraging or migratory 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 such as forests, wetland and hedgerow networks, and habitat features such as individual trees, waterbodies or water courses likely to be utilised by bats should be taken into account. Their presence will increase the likelihood that bats may forage in these areas. Very open habitat 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 migratory population. More details are found in Bach and 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 their annual life cycle. A typical year in the life of bats involves a period when they are active (usually April - October) and a period when they are usually less active or in hibernation (November to 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 species are much more active during winter than other species of bat. 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 on 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 to 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 deconstruction 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 are frequently migratory species (Ahlén 1997, Ahlén 2002, Johnson *et al.* 2003, Petersons 1990). Bats from local populations may also be affected (Arnett *et al*. 2005, Brinkmann *et al*. 2006). Therefore an environmental impact assessment 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. In these locations the wind farm can have an effect, as is typical in the plains, but its site and construction in forest areas can also affect bat habitats. Bat foraging habitats can be affected and roosts destroyed by the site clearance to build turbines and access roads, and the placement of cables connecting to the power network.

The assessment methodology must take into account the summer, spring and autumn migration aspects, in order to avoid and mitigate the impacts satisfactorily. It is recommended that planners (after consultation with bat experts) consider and assess potential impacts on bats when considering applications for all proposed wind turbines (e.g. Ahlén 2002, Bach and Rahmel 2004, Behr and v. Helversen 2005, Brinkmann *et al.* 2006, Dürr and Bach 2004, Endl *et al.* 2005, Johnson and 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 Environmental Impact Assessments (EIA) requirements, where appropriate. Where certain development is likely to have significant environmental effects on bats (e.g. effects on either/and 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 recommended that a pre-survey assessment be undertaken for all new inland and off-shore 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 making and whether a more detailed survey is required.

Consideration should be given to including 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 identify potential habitats for bats and impacts that may arise from a proposed wind turbine.

These should include:

- Aerial photographs/maps/habitat survey map
- Species distribution maps/consider species distributions
- Records of known roosts and bat sightings. For off-shore sites this should include records from oil rigs, lighthouses and other open sea or coastal records
- If possible bird migratory routes as they can give us a hint on bat migration as well
- European bat migration data

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

- Local bat groups
- Biological Records Centres

- o Wildlife Trusts
- o Statutory Nature Conservation Organisations
- o Bat Conservation Trusts
- o Natural History Museums
- o University research organisations
- o Provincial authorities
- o Consultancies 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 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, what landscape features are good for bats (roost, foraging, corridors) and what 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 potentially can result in the following impacts:

- o Death through collision with rotary blades
- o Disturbance or severance of migration routes
- o Disturbance or severance of local commuting routes
- o Disturbance or loss of foraging habitat
- o 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 and also long distance movements of bats between summer and hibernation sites, particularly migration routes/major movement e.g. autumn movement /swarming.
Migration routes over land and off-shore 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 off-shore 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 10km 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.

Larger wind turbines 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 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 quarters, when maternity roosts disperse, or when mating takes place and swarming starts in the area.

3.2.2 Survey methods

a) Land based wind turbines

Surveys of proposed wind turbine sites should also consider the benefits of including survey techniques proposed for open space activity surveys such as hand held or automated bat detector surveys, 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 and surveys using 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 automated stations.

It has been suggested that the use of radar, sited along foraging, commuting or migratory 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. This latter technique 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 determine seasonal use of roosts within a 10 km radius. To provide an indication of migration routes, intensive survey of a 1km 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 as a rule not be installed within woodlands, nor at a distance less than 200 m 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 interest should be the bat activity above the canopy. Imaging cameras and kites/balloons with bat detectors will give an indication of height. Radar, if they prove to be operational, may be less useful here than in less cluttered habitats. Focus on species using open spaces as well as all species known to fly above the canopy e.g. *Pipistrellus* sp*., Hypsugo savii, Myotis bechsteinii, Barbastella barbastellus, Myotis nattereri, Myotis myotis, Eptesicus* sp*., Vespertilio murinus* and *Nyctalus* sp.

b) Off-shore wind turbines

Off-shore wind turbines should be surveyed in the same manner as land based turbines, but will require surveys to be undertaken from boats, lighthouses, etc. Off-shore wind turbine surveys, however, should concentrate on migration routes rather then foraging areas. Surveys should be concentrated in spring (April/May) and autumn (August/September), unless bats are 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.

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 a) 4 Timing of survey):
- (a) Commuting between post-hibernation roosts
- (b) Spring migration
- (c) Activity of local populations, checking also for flight paths, foraging areas etc. and concentrating on high flying species
- (d) Dispersion of colonies, start of autumn migration
- (e) Autumn migration, mating roosts and territories

3.2.4 Type of survey

a) Inland survey

1. Search for new nurseries within for example a 5 km radius to help assessing the stages (c) and (d) of bat activity (May to August).
2. 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 sitting of the wind farm) and for each planned sitting of wind turbine (activity index = number of bat contacts per hour). However in the results the % of feeding buzzes should also be noted.
     - preferably the species or groups of species (see above)
   - Infrared camera (or the expensive thermal imaging camera whenever available).
3. Height surveys
   - Automatic surveys with a bat detector on board balloon, kite, weather tower or any other suitable structure (for activity index and groups of species, at all stages of activity cycle).
   - The utility of a radar in combination
     - with automatic recording of ultrasonic microphones placed at different heights on a balloon guideline (in order to have a height reference)
     - with an infrared camera

     has still to be shown.
4. Timing of survey
   Depending on the local geographical conditions and on the presence of species with a very short hibernation period:
   - **15/02-30/03**[2]: stage (a): once a week, first half of night for 2 hours starting half an hour before dusk
   - **15/03[3]-15/05**: stage (b): once a week, first half of night from sunset for 4 hours and include 1 whole night in May for stage (c)
   - **01/06-15/07**: stage (c): four times, always a whole night
   - **01/08-31/08**: stage (d): once a week, first half of night from sunset for 4 hours including 2 whole nights
   - **01/09-31/10**: stage (e): once a week first half of night from sunset for 4 hours include 2 whole nights in September and for the fist half of the night in October. During this stage one should also search for mating roosts and territories. End of September and October on the European continent, *Nyctalus noctula* have been noted in large numbers hunting in the afternoon from 5 to 100m high. Therefore the survey should start 3-4 hours before sunset, where this behaviour of *Nyctalus noctula* is suspected.
   - **01/11-15/12**[4]: stage (e): once a week (if climatic conditions are appropriate), first half of night for 2 hours starting half an hour before dusk

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[2] Applies mainly for southern Europe, for *Miniopterus schreibersii, Rhinolophus euryale* and *Myotis capaccini*
[3] If stage (a) was irrelevant in the area
[4] Same as note 4

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.

b) Off-shore survey

For off-shore 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.
- Survey from land
  - From (pointed) land marks, thought to be localities where bats leave in the direction to 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 on board kite, lighthouse or else (for activity index and groups of species)
- Survey on sea
  - Boat transects in the area of the planned wind farm (might be possible to combine with nocturnal bird census)
  - If possible from regularly nocturnal ferries crossing between two landmark tips that are believed to be important for bat migration (e.g. Bornholm-Rügen in the Baltic Sea).
  - Tracking radar from a lighthouse in combination with boat transects to check the radar determination of bats
- Timing of survey
  - 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 contacted 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, dispersion and swarming, 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 makes)
- 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 and 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 accounts of 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 bat collision 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 2 to 5 days combined with a detector survey the preceding night.

4. Monitoring the impacts

Monitoring of wind farms will establish the impacts of wind turbines and 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 present 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 the wind farm is not yet fully understood as in most cases the cause of the collision is unknown. Different hypotheses have been proposed, such as:
- Air turbulences
- A non-perception of the danger (too short series of echolocation calls by migrating species or too high velocity of the rotating blades)
- The speed of the blades is too high to be perceived by the sonar of bats
- A higher concentration of insect prey around the nacelle, which entices bats to forage in this area.

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

A comprehensive monitoring scheme should focus on at least four following research themes highlighted in Section 2: loss of habitats, mortality, migration and behaviour.

4.1 Loss of habitats

To assess if the wind farm induces a loss of habitats for bats it is necessary to know:
1. (Survey year 1) which species are present in the area before the construction, which ones are foraging on the site or passing through during migration. A reference site (see below) should also be studied.
    - Roost inventory at least in a 10 km radius if the wind farm has been built without any bat survey, otherwise just check the known roosts
    - Study of habitat use (with bat detectors on the ground and at different altitudes – infrared cameras optional)
2. (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

3. (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 below)

   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.

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 (time necessary for a predator to find the victim before man) and by the efficiency of the searcher (depending also on the type of ground cover underneath the turbines). Therefore the monitoring will present 2 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 drifted 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. If possible the radius should be the total height, but not less than 50 m.

The search area (prefer a square to a circle) will be marked out by 4 corner poles and two opposite sides with other poles indicating 10m or 5m distance bands. The transects walked from one pole to the other will allow checking a band of respectively 5 or 2.5 m wide on each side.

If for some reason the area cannot be walked entirely, the percentage of the searched area 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 will automatically be checked and some other 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 retrieved fatalities and therefore the smaller the bias of predation. An interval of 1 day between samples is suggested for small wind parks, with a 5-days interval (maximum) for larger wind farms (for comparison of results according to the time interval, see Arnett *et al*. 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

- 15/02 – 31/03 : 1 control/week or less
- 01/04 – 15/05 : 1 control every 2 or 3 days
- 16/05 – 31/07 : 1 control/week
- 01/08 – 15/10 : 1 control every 2 or 3 days
- 16/10 – 15/12 : 1 control/week or less

e) Search methods

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

The searcher will note the position of the carcass (GPS coordinates, direction to the WT, 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.

4.2.2 Estimation of mortality rate

A statistical analysis will be necessary to estimate the mortality rate on the monitored wind farm. 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 account for variable height of vegetation on the searched area. As for carnivores bat flesh is probably less attractive than bird flesh, it is advisable to use available frozen bat bodies (they will be thawed before use). But in most cases trials will have to be performed with small passerines or one-day old chickens (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

- <u>Classification of ground cover</u>
  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 *et al*. 2005 or Brinkmann *et al*. 2006. These classes are important for the statistical analysis.
- <u>Trials</u>
  The searcher efficiency will be tested with different heights of vegetation (4 times a year).
  Bat bodies will be distributed at random on the search area of some turbines, the coordinates of each location been noted (as well as direction and distance to the mast and the type and height of vegetation of each spot.
  The searcher will proceed as for a normal carcass recovery.
- <u>Use of trained dogs</u>
  A dog trained to point at bats might be used for searching for victims but its efficiency will also be tested the same way as above. A pointer dog must be preferred to a retriever, so that his master 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 migrating 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 through 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). But the cost of running radar and cameras implies that this equipment is limited to either large wind farms, problematic sitings or fundamental research.

A helium balloon (airship type zeppelin) with automatic recording of ultrasounds (via Batboxes) has been tested in France by the Museum of Natural History in Bourges and used successfully in France (Sattler and 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.

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 sittings 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 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 planning of future wind farms.
Several, recent European and American studies have identified research needs which fall into six categories:

- Methodology development
- Mortality and (population) effects
- Migration
- Collision
- Disturbance, barrier effect
- Mitigation and/or avoidance

The following section outlines the research needs and marks those that are priorities in italic. As well as highlighting the research needs, possible investigation methods are also mentioned.

5.1 Methodology development

Develop methods 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 project	Possible methods
• *Further development and testing of existing methods (such as from Arnett et al. 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 *et al*. (2005) (to provide cross 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 • Tracking 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 rate at offshore wind farms.	• Tracking radar • Boat tours • Automatic bat registration box
• Develop and test methods to investigate bat migration. Over land and sea.	• Radio tracking • Tracking radar • Ringing[5] • Broadscale, repeated and synchronized bat detector samples
• Develop and test methods models of geographical and ecologically relevant species distribution maps. This highlights the most important foraging areas across a broad geographical scale and acts in a graduated fashion (most to least important) (e.g. Jaberg and 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
- is it possible to use information on landscape characteristics to avoid or mitigate problems?
- the effects at the population level: if there is mortality, is this a problem for populations?

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

Research project	Possible methods
• 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.	• Systematically collision mortality studies throughout the whole season (methods after Arnett *et al*. 2005, Grünkorn *et al*. 2005)
• The investigation of collision rates of bats per year and per 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.	• Systematically collision mortality studies throughout the whole season (methods after Arnett *et al*. 2005, Grünkorn *et al*. 2005)
• *Potential population level impacts on bat collision mortality are completely unknown.*[6]	• Systematic collision mortality studies throughout the whole season (methods after Arnett *et al*. 2005, Brinkmann *et al*. 2006, Grünkorn *et al*. 2005) • Genetic studies • Population studies • Population models
• There is a total absence of quantitative data on the cumulative effects of onshore and offshore wind farms on migrating bats.	

5.3 Migration

Further information is needed on:
- where in space and when in time/season?
- are flyways / migration zones existing and recognizable?
- and if so, what is their relation to landscape on a rougher and finer landscape scale
- is it possible to use info on 'peak migration activity' and 'migration fly ways in the landscape' to avoid problems?

Research project	Methods
• *Identifying migration routes / corridors and step stones. There are several studies on bat*	• Bat ringing projects along migration routes • Mist netting along migration routes

[6] Not only for bat collision mortality as a result from wind farms, but also effects on the population resulting from mortality through bat traffic collision or reduced reproduction through disturbance of roosts et cetera resulting from other types of development, are not known. → this kind of research should be set up in broader sense.

migration in different isolated places of Europe, but a continuous map of migration routes or stepping stones are not available. Specific information on offshore migration paths across the Sea such as the North Sea and Baltic are missing. Studies and observations do show that bats are crossing the open Sea (Ahlén 1997, Ahlén et al. 2002, Ahlén and Bach unpubl., Russ et al. 2001, 2003, Walter et al. 2004, Hüppop pers. comm.). • *Do landscape structures (river valleys, coastal lines, valleys between mountain ridges…) guide migration?* • We need to prove and understand any anecdotal information that stepping stones are important, such as forests with traditional mating sites for *N. noctula* and *P. nathusii*	• International genetic studies (see Petit and Mayer 2000) • Radio-tracking • Tracking radar studies • Detector studies on selected migration points
• *It is not known under which weather conditions migration takes place onshore/on-land and off-shore. In general wind (and visibility) will change behaviour and routes. Only a few examples exist about different weather conditions that bats will migrate. Arnett et al. (2005) and Behr and Helversen (2005) describes the main activity at wind speed <6 m/sec. but many collisions appear at >6m/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 migratory 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 transect (hand held, automatic bat registration systems) • Thermal imaging • (Tracking) radar

5.4 Collision

Further information is needed on:
- why bats collide with wind turbines
- is it impossible / too difficult for bats to observe the wind turbine and understand the hazard?
- could they be attracted to wind turbines?
- can techniques be developed to warn off bats

Research project	Methods
• *Why do bats collide with turbines? Arnett et al. (2005) describe 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 and Helversen 2005) indicate that not only migrating bats collide with turbines, but foraging bats from the local populations as well. Migrating bats may also take the chance to forage during migration (e.g. Arnett *et al*. 2005, Ahlén and Bach unpub.). Little genetic data of 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

- We need to know more about behavioural responses of foraging local bats?
- Do they avoid wind turbines or habituate after a while?
- Does habituation result in bat collision?

Research Project	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 habitat of high flying bat species such as *Nyctalus*, *Vespertilio*, *Miniopterus* and the effect on their populations.	• Radio tracking • Detector studies • Habitat use studies • BACI (before and after construction) studies
• Generic studies are needed on the behavioural responses of different species based on life history traits,	

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 and identify the influence of turbine lighting on behavioural responses.	
• 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 disturbance displacement, 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 include habituation of bats to wind farms, which could cause the impact to decrease over time. For migrating bats such phenomena is not expected but could be possible for local bats. Significant impacts on the population only become apparent in the long term.	• Ringing • Population studies

5.6 Mitigation and/or avoidance

Further information is needed on:
- would it be possible to warn them off?
- what techniques can be developed to do this?
- is it possible to avoid or mitigate problems?

Research project	Methods
• Are there any possibilities to deter bats from wind turbines? It should be studied, to find out if different kind of noise /sound signals and/or light signals might be a possible way of deterring or warning bats or whether it might actually attract them. Bats may react negatively to strong radar.	• Noise emission studies (infra, normal, ultra sound) • Radar studies
• *Develop methods and instruments which can automatically record*	• Systematically collision mortality studies throughout the whole

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.	season (methods after Arnett *et al*. 2005, Brinkmann *et al*. 2006) • Automatic bat registration systems at high altitudes • Thermal imaging camera
• In some parts of Germany and Sweden it is known or suspected that bats roost inside gondolas. The gondolas should be closed to prevent bats from roosting inside. To reduce the risk of collision through cog wheels it is important to find ways to prevent bats from entering gondolas. It is also suspected that bats can roost also in other man-made structures, such as transformer installations. One bat was observed flying out from a transformer building (Lutsar unpub) and one *V. murinus* and one *P. pipistrellus/pygmaeus* were observed landing in the islets between 22h and 23h, in Finland (Laanetu and Masing 2004).	• 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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Table 1 - Studies done in Europe

Study (author, year, area)	time	type of turbines	methods	results	Habitat-types
Ahlén, 2002 and **Ahlén**, 2003, Sweden	August/September 2002	different	160 turbines (Gotland 66, Öland 39, Blekinge 4, Skane 51) - 1 control / turbine - search area 50m around turbine	- 17 bats (Enil 8, Vmur 1, Nnoc 1, Pnat 5, Ppip 1, Ppyg 1) - 0,1 bats/control - Gotnad 12, Öand 2, Blekinge 2, Skane - distance 3-25m (mean 12m) 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)
Alcalde, 2003, Navarra - Spain and pers.com	1995-2003	height: 40m (older model) and 60-80m blade: 20m (older model) and 34m	around 1000 turbines search area with radius equal to turbine height	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 increase with temperature and decrease with wind intensity bats use mainly areas close to trees	close to hedgerows
Bach, 2002, Lower Saxony, Germany	April 1998- September 2002	1 windfarm, 70 turbines, height 45m, blade diameter 30m	- landscape use of Eser and Ppip - systematicall detector census in the whole parc and the surroundings - 7 time / year - start one year before the turbines were built untill three years afterwards.	- 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 100m to turbines increased during the years **after all:** - Eser seemed to leave the parc after the turbines were built	farmland with many hedgerows 10-100m from turbines
Benzal & Moreno, 2001, Navarra - Spain			4 wind farms with turbines along 12,6km	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	
Behr & V. Herversen 2006, Rosskopf, Germany	end of april-mid of october	1 windfarm, 4 turbines, height 98m, blade diameter 70m	2005: April-June every 3 days, july to october every 4 days; estimation of search efficiency	2005: 31 bats (23 Ppip, 4 Nlei, 4 Pindet) =0,18 bat/turbine/night; april to mid of july: 11 bats; mid of july to mid of october 20 bats after curtailment of functioning period, the number of dead bats decreased significantly.	forest in areas with tree blowdowns
Brinkmann 2006, Freiburg, Germany	2004: august-october 2005: april-mid of may and mid of july- mid of october	different; 2004: 16 turbines 69-98m height; 44-80m 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 50m diameter around turbines; estimation of search efficiency; study with heat imaging camera	2004: 35 bats (+ 5 bats at an additional investigated site, Ppip 31 Nlei 7, Vmur 1, Eser 1); 2005: 10 bats (Vmur 1, Ppip 8, Nlei 1) no dead bats in spring	mostly forest, some at forest edges and meadows
Cosson M., 2004 and 2005, France	IBA, Ramsar site, ZPS. Bird study. Mortality checked from July 23 to December 16, 2003 and from January to December 2004	8 turbines N80 height 100m	control done for every turbine on a 1ha area from July to Dec. According to J.E. Winkelman's method 16 control of 8 turbines	40 bats (2003-2004) (Pnat 30, Nnoc 3, P spec. 5, Ppip 2). M=4,74/week (2003) M=3,1-3,6/week (2004) . For 2003-2004, M=20,3 to 23,5 bats/turbine/year	open cultivated polder on one side and oyster beds on the other

Study (author, year, area)	time	type of turbines	methods	results	Habitat-types
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 50m around turbine (mainly!)	36 bats (0,04 bat/control) - mainly Pnat, Ppip, Nnoc - at all types of turbines, mainly 1. & 2. august decade	- different - often close to hedgerows
Endl et al., 2005, Sachsen, Germany	March 2004 - November 2004	16 windfarms, 92 turbines, height 65-80m, blade diameter 47-80m	- 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 dead paper bats!	- 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 (0-150m)
Göbel & Göttsche 2005, Schleswig-Holstein, Germany	July/ first half of september	2 windfarms, 4 resp.2 turbines; 65m resp. 60m height; blade diameter 80m	16 resp. 14 controls	4 turbines: 6 bats (Ppip 1, Pnat 2, Mdau 1, Nnoc 1, Mdas 1) 2 turbines: 3 bats (Ppip 1, Nnoc 1, Pnat 1)	different: open (4 turbiens to near hedges (2 turbines)
Grünkorn et al., 2005, Schleswig-Holstein, Germany	September 2004 - mid of November 2004	3 Windfarms, 24 turbines total height 100m; 2 turbines total height 120m	- **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	- we need to search an area of the total turbine height - area should be searched for small birds/bats in a up and down transects 10m wide for small birds (bat size) (search area 10m each site) - few vegetation cover (<10%): found rate 44 % - high vegetation cover (>30 %): found rate 8 % for small birds (bat size) (search area 5m each site) - high vegetation cover (>30 %): found rate 10 % **no dead bat was found**	farmland, open arae with few trees, bushes
Haase & Rose, 2004	March-April & August-October 2004	heigt: 60m, 70m, 89m; blade diameter: 48m; 58,5m; 58,5m	- 3 controls/turbine/month - bat activity per detector in the area around the turbines (ca. 500-1000m around the turbines)	- 2 bats (Nleis 1, Plaurit 1) - 0,06 bats/control - no observed activity of Nleis, Nnoc, and Ppip close to the turbines.	farmland, 50-200m close to hedgerows and forest
Kusenbach, 2004, Thüringen - Germany	25. August - 23. September 2004	Different types (size mostly unknown!)	94 turbines (18 wind farms) - 110 controls (1-3/turbine) - chicken experiment	7 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 windturbine: 3-15m - 1 bat with oily substance on the body <u>chicken experiment</u> - 30 % found bach after 1 day - 15% found bach afer 2 days	- 20-100m from hedgerows - sometimes close to forest (3 x 200m) - known bat migration corridors
Latorre & Zueco, 1998, Aragon - Spain				6 bats estimation of number of dead bats: 274,05 bats/year estimation of number of dead bats: 10,15 bats/turbine/year 1998: 6 bats (P spec 5; Tten 1)	

Study (author, year, area)	time	type of turbines	methods	results	Habitat-types
Lekuona, 2001, Navarra - Spain	March 2000-March 2001	height: 40 m blade diameter: 40 m	1 year search area 50m around each turbine; many times only a small radius, due to vegetation	estimation of number of dead bats: 274,05 bats/year estimation of number of dead bats: 10,15 bats/turbine/year no deaths detected under electric lines 1999: total 7 dead bats (P spec 5, Hsav 1, Tten 1) estimation of death rate in 2 farms: 3,09 and 13,36 bats/turbine	different
Lekuona, 2001 and **Petri & Munilla**, 2002, Navarra - Spain	March 2000-March 2001	height: 40 m blade diameter: 40 m 10 wind farms; 400 turbines	400 turbines - bird study! 4 parcs: 1 control/week March 2000-March 2001 1 parc: 1 control/week between June2000-March 2001 search area 50m around turbine;many times only a small radius, due to vegetation	3 bats (Chirop. spec. 1, Ppip 1, Hsav 1) (2 in August, 1 in March) disappearance rate: July - 57% 24h and 70% 48h; November - 67% 24h and 80% 48h average distance (cadavers): 25m detection rate:July 13,2% and 11,6% November 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
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: 20m, 50m, 100m from turbines	- 12 x no ultrasound emission - 5 x few ultra sound emission - 13 x clearly ultra sound emission between 14 - 30 kHz - 13 types of turbines with ultra clearly sound emission **but:** the same turbine type with and without ultra sound emission	
Trapp et al, 2002, Oberlausitz - Germany				34 bats (Vmur 6, Ppip 3, Pnat 10, Nnoc 12, Nleis 1, Chirop. Spec. 2)	
Traxler et al., 2004, Lower-Austria	September 2003-September 2004	3 Windfarms, 4 turbines height 98m, blade diameter 70m; 2 turbines height 100m, blade diameter 80m	5 turbines, - 1 control / day / turbine - search area 100m around turbine - search efficiency control by bringing out dead birds!	14 bats (11 Nnoc, 2 Pnat, 1 Plaus) - collision rate (according Winkelmann) mean 5,33 bats/turbine/yea (Oberdorf: 0; Prellenkirchen 8,0; Steinberg 5,33 bats/turbine/year) - mean collision at wind speed 5-6 m/sec. - highest colision-rate in August - bats hunting around moving blades in early afternoon	farmland, 50-200m close to hedgerows and forest,

Table 2 - Bats behaviour in relation to windfarms

Species	Hunting close to habitat structures	Migration or long distance movements (>200km)	High flight	Low flight	Max. distance (m) of ultrasonic detection (D980) (data from Michel Barataud)	Max. distance (m) of ultrasonic detection (D240) (* means duting hunting) (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
Rhinolophus ferrumequinum	X			X	10								
Rhinolophus hipposideros	X			X	5								
Rhinolophus euryale	X			X	5								
Rhinolophus mehelyi													
Rhinolophus blasii													
Myotis myotis		X	X	X	30	20						**X**	**X**
Myotis blythii			X	X	?								**X**
Myotis punicus					?								
Myotis daubentonii	X	X	(in tree tops)	X	30							**X**	**X**
Myotis emarginatus	X	?	X	X	15								
Myotis nattereri	X			X	20	15							
Myotis mystacinus	X			X	15	20							**X**
Myotis brandtii	X	X		X		20						**X**	**X**
Myotis alcathoe	X			X	20								
Myotis bechsteinii	X			X	25	15*							
Myotis dasycneme		X		X		30						**X**	**X**
Myotis capaccini				X									
Nyctalus noctula		X	X		100	150	X	X	X		**X**	**X**	**X**
Nyctalus leisleri		X	X		60-80		X	X	X		**X**	**X**	**X**
Nyctalus lasiopterus		?	X		100		?				**X**	**X**	**X**
Eptesicus nilssonii		X	X			50		X	X			**X**	**X**
Eptesicus serotinus			X		50		X	X	X	X	**X**	**X**	**X**
Vespertilio murinus		X	X			50		X			**X**	**X**	**X**
Pipistrellus pipistrellus	X	?	X	X	30		?	X	X			**X**	**X**
Pipistrellus pygmaeus	X	?	X	X	?	30	?	X	X			**X**	**X**
Pipistrellus kuhlii	X		X	X	30		?	X	X			**X**	**X**
Pipistrellus nathusii	X	X	X	X	30-40		?	X	X			**X**	**X**
Hypsugo savii	X		X	X	40-50		?	X	X			**X**	**X**
Plecotus auritus	X			X	30	10*						**X**	**X**
Plecotus austriacus	X			X	30	10*						**X**	**X**
Plecotus macrobullaris	?			X	30								
Plecotus kolombatovici													
Barbastella barbastellus	X			X	30	20							
Miniopterus schreibersii	?	X	X	X	30			X				**X**	**X**
Tadarida teniotis			X		150-200		X	X				**X**	**X**