Natural England Technical Information Note TIN069

Assessing the effects of onshore wind farms on birds

This guidance identifies when and where detailed assessment of potential impacts on birds resulting from wind farm developments are likely to be required. It describes the data requirements and survey methodologies needed for such assessments, and explores particular issues such as the utility and limitations of remote technologies and collision risk models. Although all relevant issues are considered it is not possible to present an in-depth review of each method in this summary document and further reading and references are suggested below.

Contents

Introduction

The impacts of wind farms on birds include (Drewitt & Langston 2006, 2008):

- Direct loss or deterioration of habitats.
- Indirect habitat loss as a result of displacement by disturbance.
- Mortality due to collisions with turbines and associated infrastructure.
- Increased energy expenditure due to a barrier effect of larger arrays or rows of turbines.

This guidance is concerned only with onshore wind farms. For guidance on assessing offshore wind farms see *Further information* below.

At present there is little evidence that wind farms in England have a significant impact on birds, perhaps largely as a result of sensitive placement away from concentrations of vulnerable species, but also due to limited or inadequate post-construction monitoring.

Government targets for the construction of more wind farms might result in future proposals being closer to such aggregations and this is likely to increase the risk of cumulative impacts at a regional or national level.

This is a cause for concern as there is still significant uncertainty about the potential impacts of wind farms on many species. Furthermore, some studies undertaken in Europe provide evidence of significant adverse effects on species which also occur in the UK (eg Follestad and others 2007).

There is thus an urgent need for greater post-construction monitoring of wind farms in the UK to reduce the level of uncertainty regarding impacts on birds. The aim of this guidance is to help promote this monitoring and the sharing of data.

When are assessments required?

All wild bird species are protected by UK and European legislation and many are considered to be of conservation concern.

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It is thus important to understand the potential impacts of wind farms on bird populations, arising from both individual developments and cumulatively.

Some form of assessment is likely to be required for any proposed wind farm, although very small developments away from vulnerable bird species may only require a limited desk study to confirm the low likelihood of an impact. Under Environmental Impact Assessment (EIA) regulations an assessment is more likely to be required if a wind farm has more than five turbines or a generating capacity of greater than 5 MW.

Situations for which detailed assessments requiring surveys and monitoring are likely to be necessary include:

- Locations where Schedule 1 (Wildlife & Countryside Act 1981) and/or Annex 1 (EU Birds Directive) species are present in significant numbers, especially those which may be sensitive to wind farm effects (see Appendix 1).
- Locations within, or in the vicinity of, designated or proposed Special Protection Areas (SPAs), ornithological Ramsar Sites and ornithological SSSIs, again especially when used by species which may be sensitive to wind farm effects. In some cases this might include wind farms several kilometres from a designated site but which potentially affect birds from the designated site while feeding outside the site or on route to and from the site along daily or migratory flight routes. (Proposals which are likely to significantly affect SPA bird populations will also require an appropriate assessment under the Habitat Regulations.)
- Known bird migration routes and local flight paths, wetland sites and other locations where potentially vulnerable species occur in relatively high concentrations.
- Topographical features such as ridges and valleys and, on the coast, cliffs and headlands, which may funnel or otherwise concentrate bird flight activity.

In many cases existing information on bird numbers will be very limited, especially at inland sites which are generally less well studied than coastal locations. It will therefore often be necessary to undertake some survey work to confirm whether or not potentially sensitive species are present in significant numbers.

Designing an assessment

At the outset of any assessment or monitoring strategy it is important to define a clear study protocol. Protocols for bird studies will be site- and species-specific, but all should follow good scientific methods.

Pre-construction surveys will generally be required to inform an EIA. Study objectives should identify potential impacts on species of conservation importance and those vulnerable to wind farm effects, including:

- Predicting numbers of birds likely to be displaced or otherwise disturbed by the turbines, associated installations and staff.
- Predicting numbers of birds likely to be killed by collision with rotors, turbine towers and other structures such as overhead lines.

Pre-construction surveys will also provide the baseline data necessary for comparison with similar data collected post-construction.

Post-construction monitoring is necessary to verify predicted effects and also to provide essential information on collision avoidance rates and any habituation to disturbance. This information should also help measure the overall impacts of wind farms on birds at a national level (SNH 2009).

In the longer term, monitoring should improve the understanding of how birds interact with wind farms, thus facilitating the more rapid and reliable assessment of future wind farm developments and helping to hasten the consenting process.

Monitoring should be tailored to the species requirements of the site and should, ideally, be specified in conditions attached to any planning consent.

It is important that pre- and post-construction surveys and monitoring adopt a standard and repeatable approach, consistent with methods used at other wind farms. This will allow comparison between wind farms and thus the generation of more reliable estimates of impacts based on a range of studies. This in turn should help the more accurate prediction of impacts of future developments. It should also assist cumulative impact assessments for particular species as the results of similar studies can be readily combined.

For individual assessments the area studied should include the entire development footprint of the wind farm, or at least a representative sample for very large proposals (where habitats and bird usage are known to be relatively uniform), and a surrounding buffer area. The size of the buffer will vary depending on bird species present and whether they are likely to be affected, but will generally range from 500 m to 2 km in radius.

The BACI approach (Before-After-Control-Impact) is recommended as the ideal standard for impact assessments. This allows the comparison of baseline values with post-construction data, and a reference or control area which can be compared with the wind farm site before and after construction.

The reference area must be as similar as possible to the wind farm area in terms of habitat, topography, size and suite of bird species. It must be close to the wind farm but not affected by it, and should be outside the development buffer area. The use of two or more reference areas will increase the reliability of conclusions.

Although it may be difficult to find a reference area that meets these conditions or to obtain the necessary access permission if on another land-holding (which might explain the lack of reference areas in many existing studies), it would provide strong evidence of impacts (or lack of impacts) of wind farm operations.

See Whitfield & Madders (2006a) for more information on the BACI approach and other study designs.

Data requirements

Pre-construction

Consideration of environmental factors and early consultation during the selection of the development site should provide an opportunity for a valuable first filter to identify potential issues that will need to be addressed.

Once initial site selection has occurred, the first stage of any assessment is to undertake a preliminary site evaluation. This involves identifying the species present and their activities on the site, as well as evaluating the use of the wider geographical area to provide context.

Such information may be available from various existing sources, including Natural England (eg location of national and local designated sites and presence of Biodiversity Action Plan species) and other conservation bodies such as the RSPB, BTO (Wetland Bird Survey data, etc), county bird recorders and other local experts. The National Biodiversity Network (NBN) is also a useful source of data (**www.nbn.org.uk/#**).

A desk study of information sources and available literature might allow an early appraisal of the habitats and species present and can help to target fieldwork and identify gaps in knowledge. However, due to the often anecdotal and incidental nature of these data, this initial assessment will rarely be sufficient to rule out the need for dedicated field surveys.

Pre-construction baseline data should include information on:

- land use;
- habitats;,
- topographical features; and
- bird species and their numbers, distribution, and time of occurrence in and around the proposed wind farm area.

Field observations should be focused on birds of conservation importance or high concentrations of birds, especially those sensitive to wind farm effects, or which show behaviours which may cause them to be susceptible (see Appendix 1 for a list of the most relevant species).

All records of bird activity should include:

- date
- time of day
- behaviour (eg, nesting, displaying, feeding, roosting)
- distance from nearest turbine position
- slope aspect
- weather conditions

And, where relevant:

- flight direction
- flight behaviour (soaring, displaying, hunting) and
- height above ground.

Similar data should be collected in the reference area.

It is not appropriate to collect baseline data during construction as this may have a negative effect on bird numbers and may lead to an underestimate of the effects of the wind farm when operational. All data should be presented as part of the Environmental Statement so that the basis for any conclusions is transparent and subject to scrutiny.

Bird data should be collected for at least one year (or the relevant season(s) if important numbers of birds are known to be present for only part of the year) in both wind farm and reference areas.

For species which show significant inter-annual variation in abundance then data should be collected for a longer period (for example hen harriers and short-eared owls require a minimum of two years' data under SNH guidance). Additional years' data should also be collected for species of high conservation priority, particularly those sensitive to wind farms.

Longer periods of data collection will increase the reliability of comparisons with similar post-construction data. Flexibility may be needed with regard to redesigning/retiming survey visits as information is gathered on bird usage of the site.

For collision risk assessments, observations of bird movement patterns and flight frequency should be undertaken using vantage point watches (see below) during a range of weather conditions (visibility, precipitation and wind speed), including at night (using light-enhancing/thermal imagery equipment and/or radar) and across the tidal cycle where relevant.

Observations during conditions of high wind speed and/or poor visibility are important as, although fewer birds might fly in such conditions, weather has a potentially large effect on flight behaviour and therefore collision avoidance (Madders & Whitfield 2006).

Where it is not possible to obtain data during bad weather, due to the limitations of observation methods or health and safety reasons, it should be feasible to use existing weather data to at least determine the frequency of weather conditions which are likely to increase collision risks for birds.

Observations of bird movements should include:

- estimates of flight height (in height bands which match anticipated or actual rotor height as closely as possible – see Whitfield & Madders 2006b),
- direction; and
- information on flight behaviour.

These data should be used to calculate the mean annual number of bird movements through the wind farm at rotor height and thus, ultimately, collision risk.

Finally, it may be beneficial to set up steering groups to devise the scope and methods of an assessment and to address the need for changes in methodologies or additional data as potential effects are identified and better understood.

Post-construction

Post-construction surveys should be targeted to address the key priorities identified during the environmental impact assessment. As with pre-construction work, surveys will typically be required to estimate population size and to provide accurate information on bird distribution and movements.

Monitoring should continue pre-construction surveys in order to determine changes, and the likelihood that these changes might be caused by the wind farm. Post-construction monitoring should thus be as similar to the baseline survey methods as possible, including time of year, observer effort and survey techniques.

The duration of post-construction studies will depend on issues identified by the EIA, but should be sufficiently long-term to assess any cumulative effects over time (or decreased effects, eg due to habituation).

At least five years' data should be collected (eg Stewart and others 2007). In locations where there is potential for impacts on birds of conservation concern, monitoring should ideally be undertaken for 15 years, with surveys undertaken in years 1,2,3,5,10 and 15 (SNH 2009).

Short-duration studies are liable to suffer from sampling biases and are more likely to underestimate collision fatalities in cases where collisions are relatively rare (Whitfield & Madders 2006a).

The regular review of post-construction studies will allow methods and timing to be refined as appropriate to particular circumstances.

It is equally important to monitor bird movement patterns and flight characteristics through the wind farm following construction as this will enable the degree of displacement from the wind farm (due to disturbance and barrier effects) to be measured. This is essential if measurements of 'true' avoidance of collision (ie near-rotor avoidance, as opposed to displacement plus avoidance of rotors) are to be calculated (Pendlebury 2006).

The collection of collision victims is necessary to estimate:

- the total number of birds killed;
- factors causing variation in collision rates (eg season, turbine type, location) and
- the efficacy of any mitigation measures.

It is essential that the results of corpse searches are subject to correction for observer detection and scavenger removal rates (eg Smallwood 2007).

Experimental approaches to calculate detection and scavenger removal rates should use corpses of similar size and colouration to species under consideration. Ideally, background mortality levels should be established pre-construction and post-mortem should be carried out on all corpses recovered. This subject is covered in greater detail below under Collision Monitoring.

Finally, where a representative sample area of a large wind farm has been used to establish baseline data, the same area should be used for post-construction monitoring.

Data collection

Survey/census techniques

Skilled and conscientious observers should be employed and provided with clear objectives and methods.

Inter-observer differences may be a large source of bias, particularly when comparing studies. It is therefore important that observers receive adequate training and that their observations are calibrated to reflect acuity skills and experience (see Madders & Whitfield 2006).

Assessment of bird numbers, distribution and activities including nesting, feeding or roosting should employ standard survey protocols (eg Gilbert and others 1998, Hardey and others 2006).

Survey periods depend on the species present and their use of the site. Generally, surveys for breeding birds should be undertaken from March to July and surveys for wintering birds from November to March. Important movements of birds can take place at any time of the year, particularly from March through to October for passage birds and also during late autumn and winter, especially in response to cold weather conditions.

For breeding birds the Common Bird Census (CBC) approach is suitable for many species (the Breeding Bird Survey approach is not appropriate) although more specialised techniques, notably transect methods with distance sampling, are likely to be necessary for certain species and species groups (see Gilbert and others 1998 for further information). Any proposed deviation from standard methods should be agreed beforehand with the relevant consenting authority.

Ideally surveys should be undertaken at least once every two weeks during the breeding season. Intensive surveys of breeding birds of particular conservation concern could employ rings or other markers to monitor and measure impacts on local populations (eg Thelander & Smallwood 2007).

For non-breeding birds at least one or two visits per month are recommended (weekly for passage birds), and the Wetland Bird Survey methodology (WeBS) will usually be appropriate for waterbirds (see Gilbert and others 1998).

Study protocols in coastal habitats must ensure coverage of different tidal states (ie high and low water periods during spring and neap tides).

Monitoring passage birds can be problematic as it is often difficult to predict peak migration periods, which may be subject to weather conditions. It is recommended that monitoring of passage movements is undertaken at least twice weekly and at even greater frequency during peak migration.

Study methods must be tailored to the ecology of the study species and, where appropriate, cover dawn, dusk and nocturnal movements. See SNH (2005, 2009) for further detail on bird monitoring approaches and Langston & Pullan (2003) and Morrison and others (2007) regarding sampling frameworks.

Vantage point observations

Fixed point or vantage point (VP) observations are necessary to collect data on flight behaviour of target species, including information on flight direction, duration and height. Such observations are essential to quantify collision risk.

Critically, VP data are necessary to show changes in flight behaviour post construction, including avoidance of the wind farm which is essential for the calculation of true 'near-rotor' avoidance rates. The following is a brief summary of the VP approach and further detail should be sought from SNH (2005, 2009).

Information is collected during timed watches from strategic vantage points covering defined areas extending from 100 m to 500 m beyond the limits of the development, depending on surrounding topography, habitats and the focal species.

The overall amount of time needed for VP observations also depends on the species and their use of the site. It is recommended that observations are undertaken for a minimum of 36 hours per VP per season (minimum 72 hours recommended when priority species such as raptors are present).

A season could be a general period, such as November-March for winter, mid-March to July for breeding and spring passage, and mid-July to October for autumn passage, or a more accurately defined period for a particular species of concern.

The more data available on bird movements the more reliable the outputs from any subsequent collision risk assessment. VP effort can be stratified against flight activity levels to ensure maximum efficiency (which may be strongly influenced by other factors such as dawn and dusk movements between roosts and feeding areas and tidal cycles in the case of coastal waterbirds).

Ideally the total amount of time dedicated to VPs should be determined by undertaking a power analysis of data collected over a trial period to ensure adequate sample sizes without unnecessary expenditure of effort (see Madders & Whitfield 2006).

It is recommended that VP observations are restricted to focal species of importance as attempting to record too many species might mean that movements go unrecorded (thus leading to underestimates of collision risk, see Madders & Whitfield 2006).

VPs should be strategically located to record movements across the site and to determine areas of low and high flight activity.

The precise number and location of VPs will depend on the type of flight behaviour and site topography. For example, fewer VPs may be needed if birds use fairly predictable corridors through a site, such as between nesting and feeding areas, and more will be needed to observe less predictable movements such as ranging activity by territorial and non-territorial raptors and migratory movements across a broad front (Madders & Whitfield 2006).

It is recommended that the position of VPs is accurately recorded using a GPS. VP locations should be selected to maximise visibility and coverage of the survey area. Except for specific studies of large birds (eg eagles and herons) all parts of a survey area should be visible within 1 km of a VP. This is because scanning with binoculars would be necessary at greater distances (for anything but the largest birds) which might lead to (often large) proportions of birds being missed and great differences in data quality between observers.

The need for closely spaced VPs must be balanced against the need to use the least number of VPs necessary in order to reduce disturbance to target species. Where feasible, VPs should be outside the survey area to prevent disturbance to birds inside the study area. This will not be feasible for larger installations, but may not be too problematic as long as VP observations are not being made within 500 m of the observer (though some observers find that observations can be made considerably closer than 500 m if using a car as a hide) and that the VP does not fall in an area under observation from another VP at the same time (Madders & Whitfield 2006, SNH 2009).

See Madders & Whitfield (2006) for a more detailed discussion of potential limitations of the VP approach (including disturbance effects, overlapping observations, differences in observer acuity, and variable detection depending on species, topography and weather conditions) and suggested solutions.

VP observations for raptors (and other resident species) should provide adequate temporal coverage depending on phenology and changes in flight activity with season (eg during breeding and non-breeding periods including migration) and different seasonal behaviour patterns (eg pre-breeding territorial activity, fledging, post-breeding dispersal).

It is also important to stratify observations, to increase the proportion of observations at the times of day when species are known (from preliminary surveys) to be most active, which may vary depending on species. Observations should be made from dawn to dusk at least once every two weeks during periods of high activity.

VP recording methods differ for target species and secondary species. Target species (for example, SSSI/SPA interest features or those listed in Appendix I) are followed until they cease flying or are lost to view, and flight routes are plotted onto a map.

The numbers and activities of non-target species are simply summarised during 5-10 minute periods during no more than two-hour watches. Although SNH (2009) recommend no more than three-hour watches, this longer period risks observer fatigue and thus underestimation of bird movements. See SNH (2005, 2009) for further detail.

Information collected for non-target species should include:

- the number of birds;
- direction and distance from observer;
- estimated height above ground;
- flight direction; and
- distance from nearest turbine.

Flight height can be estimated using nearby structures and/or a clinometers but note that flight height estimates are prone to observer error and it is important to train observers in flight height and distance estimation (Madders & Whitfield 2006). It may be possible to correct for consistent errors using staged exercises with targets of known height and distance.

Nocturnal observations

A thorough review of techniques for recording nocturnal bird activity, including case studies, is provided by Kunz and others. (2007). Such techniques should be employed in situations where nocturnal bird activity is likely, including nocturnal migration and foraging activity of owls, nightjars, waders (in particular golden plover) and wildfowl.

Available methods include night-vision observations, thermal infrared imaging, radar monitoring, acoustic recordings and radio-telemetry. Some of these methods are equally applicable to daytime movements and are covered in more detail below under remote techniques. It is important to note that nocturnal surveys require significantly more time than diurnal surveys due to the need to scan large areas from multiple observation points.

Night-vision imaging employs night-vision goggles and telescopes, powerful spotlights and reflective infrared cameras. This includes image-intensifiers (which make use of ambient light) and the combination of infra-red detectors and infra-red spotlights).

Recent technological improvements allow greater freedom to follow and identify birds, the use of fixed and mobile spotlights that increase the ability to detect and identify birds correctly, and infrared filters that eliminate the attraction of birds to light sources.

It is possible to identify small birds at distances of up to 150 m and to record flight direction, altitude and behaviour, and to take video recordings for later analysis. Limitations of the method include variable detection of animals due to cloud cover and ambient light levels, atmospheric moisture and distance. Night-vision devices also produce visual noise which make it difficult to distinguish small birds from bats.

In contrast to night-vision technology, thermal infrared imaging cameras detect heat emitted from objects without the need for ambient or artificial illumination. Images can be captured at rates of 30 to 100 frames per second and digitally recorded to computer hard drives.

Range, field of view and recording resolution differ depending on equipment, with a trade-off between range and field of view. For example, wide angle equipment can distinguish objects at a distance of 100 m whereas powerful telephoto equipment with a narrow field of view can detect small passerines up to a distance of 3 km.

Many of the limitations of other visual methods are common to thermal infrared imaging, which is also relatively expensive and has large data processing requirements.

Results from night vision and thermal infrared imaging ideally should be supplemented by other methods including radar and acoustic detection, which provides information from a wider area and the potential for species identification respectively. For example, Gauthreaux and Livingstone (2006) used a thermal imager in combination with fixed-beam vertical pointing radar to monitor bird movements based on the characteristics of tracks in the video image and the altitude of targets derived from the radar unit.

Remote techniques

Remote techniques can provide information which is additional or supplementary to visual studies and, with appropriate ground-truthing and calibration, can also overcome bias caused by disturbance effects associated with human observers.

Current approaches include radar, video cameras and thermal imagery, with other approaches such as radio-telemetry and satellite tags in recent development for wind farm studies. Vibration sensors and acoustic monitoring are also under development (Wiggelinkhuizen and others 2006) but may be more relevant to offshore developments where corpse searches are not feasible.

Radar

Although expensive, radar offers an important advantage over visual observations in that it provides continuous and simultaneous sampling over a large area.

It also allows observations both day and night, and in a range of visibility conditions (though limited by high moisture levels). It is therefore of particular value for tracking local foraging and roosting movements and long distance migration.

A combination of horizontal and vertical radar systems can measure both flight direction and height, thus helping to identify risk preconstruction, and recording behavioural response of birds post-construction, such as avoidance of turbines (Desholm & Kahlert 2005).

Radar could also be very useful in measuring flight elevation and speed (an important collision modelling parameter) at the site level rather than relying on data from other studies which might be inappropriate.

Fan-beam marine radar is the technology most commonly used to track bird movements, although it is impaired by rain and fog and has a relatively short range (around 11 km) which may be considerably further reduced by topography and target size (eg the body size of a bird).

Marine radar technology is relatively inexpensive, requires little modification or maintenance, has a high resolution, can be modified to collect both horizontal and altitudinal information, and is highly portable (ie can be mounted on vehicles).

Large-scale surveillance radar has a longer range and fixed-beam or pencil-beam tracking radar can provide detailed information on the movement of individual flocks, but are more expensive and difficult to use.

Due to the 'shadow' caused by turbines and moving rotors, radar is generally not able to detect collisions, and other remote technology would normally be required to provide this information (see below). Supplementary species identification by visual/auditory observations is also necessary, although more sophisticated systems can use wing-beat signatures to identify certain species or species-groups.

In order to correctly quantify bird migration:

- radar must be calibrated;
- echoes correctly identified as birds; and
- the radar survey volume must be accurately estimated.

Calibration is important to estimate the surveyed volume and set a distance-dependent detection threshold in order to eliminate echoes of insects and 'clutter' (caused by vegetation, waves etc.) close to the radar antenna.

Radar echoes must be identified as birds based on the radar cross-section (ie the size of a target as seen by radar) and the echo signature. The echoes of particular bird groups can be recognized (eg wader-type, raptors) but species can only be identified by simultaneous visual observation (or by their calls – see below).

The survey volume depends not only on the maximum detection range and specifics of the radar antenna, but also on the radar cross section of the birds studied (which depends on size, shape and aspect), with clearer tracks obtained for larger birds at closer range. The requirements for ground-truthing should not be underestimated.

One of the most important aspects of using marine radar is the selection of suitable sampling locations, which has important implications for data quality and comparability between sites. Radar antennae must be located where ground clutter and shadow zones do not obscure important parts of the study area.

For further information on radar techniques and limitations see Desholm and others (2005, 2006), Kunz and others. (2007), Schmaljohan and others. (2008) and Walls and others (2009).

Currently only the Central Science Laboratory (CSL), in the UK offers the combined service of radar equipment, experienced operators and the necessary software to filter potential bird targets from other radar returns. This equipment employs both S-band surveillance radar to detect birds in the horizontal plane and X-band in the vertical plane, with an 11 km radius for large birds individually or in flocks. A database of bird tracks is stored and output to ArcGIS, which allows the interpretation and statistical analysis of bird movements (see Allan and others (2004) and the link below for further information).

Thermal Animal Detection Systems (TADS)

Researchers in Denmark have piloted TADS at offshore wind farms. The systems employ an infrared video camera to record flight behaviour, collisions and avoidance responses close to rotors.

The camera is mounted on a turbine tower and points up towards rotors and can identify species using a combination of bird silhouette, flight behaviour and size. TADS requires the setting of a pre-determined thermal range to trigger image recording and is operated remotely using specialised software.

Due to a trade-off between field of view and image resolution the technology currently available allows only a very limited field of view (restricted to one third of rotor swept area of a single turbine) and small birds can be viewed only at close range.

Pilot work shows that there is a very low probability of an individual camera recording a collision event due to this limited coverage, and that cameras would be needed on several turbines simultaneously to be effective.

Despite current limitations TADS has the potential to provide information in conditions of poor visibility and at night, and could be used to supplement other methods such as corpse collection (see below). For further information see Desholm and others (2005, 2006).

Acoustic monitoring

Acoustic monitoring, which is particularly valuable for nocturnal migrants, can be used to assist the identification of species recorded by radar and TADS (Evans 2000).

The use of several directional microphones is necessary to obtain information on location and flight altitude. Microphones must have good sensitivity in the 10 kHz to 1.5 kHz range and low internal noise levels. Importantly, both microphones and preamplifiers (required to amplify weak signals from the microphone to allow recording without distortion) must be resistant to extremes in moisture and temperature.

The most serious problem with acoustic monitoring is the masking of flight calls by ambient noise, including wind noise and turbine nacelle and rotor noise when undertaken post-construction, although software has been developed to filter out such background noise (eg Hill & Huppop 2008).

Identification of flight calls depends on sophisticated voice-recognition technology (which is currently limited in its application) or an expert listener able to provide more comprehensive identification (Kunz and others 2007).

The use of acoustic monitoring to estimate numbers of birds is complicated because not all species call at night and, of those that do, not all individuals will call as they pass a microphone. However, correlations of numbers of flight calls with numbers of radar targets suggests that flight calls may provide an index of migratory activity, at least in some circumstances, and thus provide information which is difficult to obtain by other means (Larkin and others 2002).

Other techniques

Vibration detectors (highly sensitive microphones) can be deployed to detect actual collisions with rotors and turbine towers and perhaps could be used to trigger carcass searches (see Pandley and others 2007, Wiggelinkhuizen and others 2006).

Satellite- and radio-tagging techniques are suitable for some scarce species, for example raptors and owls (eg Hunt and others 1999, Follestad and others 2007), though satellite receivers and transmitters are currently too large to be used on smaller non-passerine and passerine birds.

In conclusion, remote techniques may be the best way forward to record bird behaviour and collisions at wind farms. Improvements to reliability and reductions in unit price is necessary to allow installation at a large proportion of turbines, this would provide information on possible large differences in fatalities at individual turbines.

Collision monitoring

Collision mortality data are important to verify the predictions of collision modelling and the success of mitigation measures. Of equal importance, reliable mortality estimates can be compared with flight frequency through the wind farm to allow the back-calculation of collision avoidance rates or indicate potential biological impacts.

Accurate avoidance rates for a range of species and under a range of conditions are essential if collision modelling is to generate reliable predictions of fatality levels at future developments (see below). Ideally, all consented developments likely to result in greater than negligible levels of collision mortality should be required to undertake and report the results of fatality monitoring programmes. Accordingly, all collision monitoring studies should employ the same methods to make results directly comparable.

Collisions are generally rare events (although not necessarily inconsequential) and thus detection by visual observation is normally impractical. Consequently, collisions on land are usually detected and measured by corpse collection.

The most efficient collection method (for rows of turbines) is for two observers to walk on opposite sides and both ends of a row, in a tight zigzag pattern perpendicular to the turbine row, and in a plot with edges a minimum distance from the turbine equal to the maximum tip height of the turbine. Additional parallel transects further away from turbines might be needed to search for corpses thrown well beyond the rotor-swept area (see below).

All dead birds found should be recorded and carefully examined to determine species and probable cause of death, general condition of the carcass and evidence of scavenger activity.

Corpses can be removed for post-mortem or left in situ and marked to allow measurements of scavenger removal rates, though this might lead to reduced scavenger rates due to ‘swamping’ (again, see below).

Corpse searches must be carried out frequently, ideally every other day or at least once a week when many birds are present, depending on scavenger activity, during each relevant season, at a sufficient sample of turbines and for at least three years (Smallwood & Thelander 2008).

Ideally, a stratified programme of searches should be based on the most relevant season(s) with regard to bird movements and vulnerability (eg Everaert & Stienen 2007).

Trained dogs may improve effectiveness of searches (Arnett 2006; Follestad and others 2007).

Paired observers may be used initially to calibrate potential differences between observer abilities. Ideally, the same observers should be employed throughout the study to reduce bias resulting from differences in searcher efficiency. It is generally not appropriate to use wind farm operational/maintenance staff to undertake corpse searches as a lack of systematic effort will lead to erroneous estimation of fatalities.

Mortality estimates can be expressed as the annual number of fatalities or as the annual number of fatalities per unit representing the size or magnitude of the installation (Smallwood 2007) and can be expressed per megawatt hour of potential output (Smallwood & Thelander 2008). Reporting fatalities per megawatt hour allows comparisons of the effects of wind farms of varying size and output.

Strict protocols are necessary to correct for various biases and allow for the comparison of results from different installations. Measures of mortality can significantly underestimate fatalities if not adjusted to account for search effort and corpse detection rates (which vary with searcher experience, corpse size, vegetation cover and time of year) and removal by scavengers (which varies with scavenger abundance, corpse abundance and size, smaller birds being removed more quickly – see Smallwood 2007, Smallwood & Thelander 2008). For example, in one study of search efficiency it was found that, on average, only about half of the corpses were found by human observers. Therefore, corpses found must be considered to represent the minimum mortality estimate. See Langston & Pullan (2003) for more information on corpse collection and factors which affect detection.

Correction factors for search efficiency and scavenger removal must be calculated for each development, as extrapolations between different developments will yield unreliable results.

Detection trials should be used to calibrate searcher efficiency, ideally using birds of a similar size and colour to the species of interest. Corpses should be placed to simulate the carcass conditions typically found by searchers (see Smallwood 2007). Partial dismemberment and feather scattering will help to mimic actual fatalities (SNH 2009). Note that searcher detection trials can be biased if searchers are aware of the trial (eg due to the presence of much higher numbers of corpses than usual) and consequently put more effort than usual into finding corpses.

Strong winds or gusts, the speed of rotor rotation, and the approach angle, speed and body size of the colliding bird can all contribute to the trajectory of the collision fatality. If trajectories carry corpses beyond the search radius immediately below turbines then this will result in underestimates of mortality. SNH (2009) suggest that a distance sampling approach can be used to account for this source of error.

Scavenger removal rates can be estimated by marking locations of found corpses (eg GPS) and measuring time to removal, or experimentally by leaving marked carcasses to assess both scavenger removal and search efficiency. Again, carcasses should match focal species as closely as possible. Depending on focal species, appropriate surrogates for removal experiments include domestic poultry, fresh (or defrosted), or shot quarry species.

The number of placed carcasses should be adequate for sampling purposes, but not so numerous that scavenger activity is increased artificially. Scavenger-swamping may result if large numbers of carcasses are used, resulting in more corpses being provided than scavengers can remove. Remaining carcasses may become unattractive to scavengers and will thus result in higher estimates of the number of days for corpse-removal, thus leading to underestimates of mortality (Smallwood 2007, SNH 2009). Ideally, an appropriate sample size of placed corpses should be determined by sensitivity analysis.

Placement and checking of corpses should avoid disruption to focal species. Trial carcasses should be checked daily or placed in front of event-triggered cameras. The checking rate can be reduced in subsequent weeks. Information on numbers of fatalities should be presented as both raw and corrected numbers.

Post-mortem may be necessary to determine the likelihood that cause of death is due to collision and will help to measure ‘background’ mortality levels (which are likely to be low in most cases).

Another potential cause of underestimation is so-called ‘crippling bias’, where injuries sustained by non-fatal collisions with rotors (or collisions with the ground caused by the effect of air turbulence downwind of the rotors) allow birds to survive long enough to move outside the search areas. It is not possible to correct for this source of bias and thus all mortality estimates will be conservative to an unknown degree.

False zeros for turbines or turbine strings with very low mortality might be obtained due to the low detection rates. Note that correction factors cannot be applied in the case of apparent zero mortality levels. See Madders & Whitfield (2006a) for further discussion of bias, particularly underestimation of bird abundance/movements versus underestimation of fatality levels, and Winkelman (1992), Everaert & Stienen (2007) and Smallwood (2007) for further information on mortality adjustments.

A case study of collision monitoring employing corpse collection is presented in Appendix 2.

Collision risk modelling

Mathematical models are used to predict collision mortality and this includes the Band model used in the UK (Band and others 2007). This is two-stage model which first estimates numbers of bird flights through the rotor-swept area and then calculates the predicted proportion of birds that would be hit. The model assumes no near-rotor avoidance although, in reality, there is generally a high recorded level of avoidance (typically >95%) for the majority of species studied.

Chamberlain and others (2005) discuss the limitations of the Band model. As with all models, the quality of the underlying data is critical to achieving reliable model outputs and a significant limitation of collision models relates to data collection.

Bird surveys are usually carried out in good weather conditions and in daylight. As bird flight behaviour is likely to be different under poor weather conditions with poor visibility and/or strong winds, or very low wind speeds, and low cloud base or at night, any assessment which excludes observations during these conditions might result in a significant underestimate of collision risk.

Another serious limitation relates to the application of avoidance rates to model outputs to generate estimates of likely collision rates. Unfortunately, there is still very little information on actual avoidance rates. The application of avoidance rates for different species at different locations to that being assessed can yield unreliable estimates of collision mortality. This is due to inter-specific differences in risk due to behaviour and varying risk due to a range of site-based factors including turbine dimensions and layout and surrounding topography.

The consequences of error when calculating avoidance rates are profound as even small changes in the rate of avoidance have very large effects on mortality predictions. Where error in measurements is estimated, it is recommended that upper and lower limits as well as mean values are used in calculations to give a range of collision risks and mortality estimates.

The inference (back-calculation) of avoidance based on observed mortality rates compared with estimations of total bird movements through a wind farm are subject to several sources of error, as described above. Thus, a better approach to the study of avoidance would be through direct observations of bird near-rotor behaviour and collisions using remote technology.

It is therefore important to use avoidance rates with caution. Ideally, avoidance rates should be derived from studies of the same species in similar situations to that being assessed. This is rarely possible and so it is recommended that a range of avoidance rates should be used to give a broad indication of worse to best case scenarios, followed by discussion of factors which may influence which end of the spectrum is likely to be more realistic.

Mortality levels predicted using a single avoidance rate must be justified by demonstrating that critical variables, such as species, weather conditions, topography, wind turbine design and wind farm layout, are sufficiently similar to the proposed development to allow an analogy to be drawn. In such cases, the original derivation of the avoidance rate should be critically examined for possible errors (Chamberlain and others 2005).

Post-construction monitoring of collision mortality is essential to increase information on avoidance rates for a range of species under different environmental conditions and how avoidance rates might change depending on age, experience and stage of breeding season/annual cycle.

Considerable uncertainty will remain until more, well-designed studies of flight behaviour within wind farms generate results that will improve the estimates of avoidance.

Data availability

Pre- and post-construction data, and the results of comparisons which indicate effects (or lack of effects) on birds should be made widely available.

This will not only provide transparency relating to methodologies and data reliability, but will also facilitate the identification of significant trends in the response of birds to turbines as well as studies of cumulative impacts of wind farms on bird populations.

To allow such comparisons it is critical that a standard approach to data collection, collation and presentation (eg expressing collision rates in terms of megawatt hours) is adopted. Ideally, publications should include all raw count data, thus allowing maximum transparency and flexibility in future interpretations and application of monitoring information.

Data should, wherever possible, be made freely available on the internet, with a longer-term goal of placing all future data in a central repository benefitting from regular updates and maintenance.

Summary

Assessments of potential impacts of wind farms on birds are required under a number of situations. To undertake such assessments it is essential that reliable and representative baseline data are collected to facilitate both preconstruction impact assessments and comparison with post-construction data to verify predictions and to provide important information on collision avoidance rates and habituation. It is therefore essential that surveys and monitoring adopt a standard, repeatable approach allowing comparison between different studies.

The Before-After-Control-Impact (BACI) approach is recommended as the ideal standard. The design of any monitoring protocol should include clear objectives at the outset in order to ensure that all data is fit for purpose.

A standard approach should be adopted for data collection, collation and presentation, and all data should freely available, ideally through publication on the internet.

Further information

Natural England Technical Information Notes are available to download from the Natural England website: **www.naturalengland.org.uk**. Including:

- Technical Information Note TIN008: *Assessing ornithological impacts associated with wind farm developments: surveying recommendations*. (Aimed specifically at assessing the impacts on key species associated with SPAs in the vicinity of the Humber Estuary and includes species-specific information on survey techniques which can be used to supplement the wider guidance provided by TIN069.)
- Technical Information Note TIN051: *Bats and onshore wind turbines interim guidance*
- Technical Information Note TIN059 *Bats and single large wind turbines: Joint Agencies interim guidance*

For further information contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**. Also see:

- *A Review of Assessment Methodologies for Offshore Windfarms* **www.offshorewind.co.uk/Pages/Publications/Latest_Reports/Birds/A_Review_of_Assessmentd5621af8/**
- Central Science Laboratory radar equipment **www.fera.defra.gov.uk/wildlife/birdManagement/birdRadar.cfm**

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Appendix 1

Detailed environmental impact assessments and monitoring are likely to be required in locations used by nationally (or regionally) important populations of the following species. Population figures refer to individuals unless otherwise stated.

Species	Population size, England	Season
Bittern *Botaurus stellaris*	Breeding: 76 males (2008) Winter: 50-150 (1981-84)	Year-round
Little egret *Egretta garzetta*	Breeding: 380-431 pairs (2008) Winter: 2,600 (1999-2004)	Year-round
Grey heron *Ardea cinerea*	Breeding: 8,000 nests (2002)	Breeding
Bewick's Swan *Cygnus columbianus*	6,691 (2003-04)	Winter
Whooper swan *Cygnus cygnus*	4,000 (2000)	Winter
Bean goose *Anser fabalis fabalis* *Anser fabalis rossicus*	169 (2006) 53 (2005)	Winter Winter
Pink-footed goose *Anser brachyrhynchus*	140,000 (2003/04)	Winter
European white-fronted goose *Anser albifrons albifrons*	2,345 (1999-2004)	Winter
Dark-bellied Brent goose *Branta bernicla bernicla*	77,500 (1999-2004)	Winter
Honey buzzard *Pernis apivorus*	33 confirmed breeding pairs, 36 probable/possible breeding pairs (2000)	Breeding
Red kite *Milvus milvus*	500 breeding pairs (2008)	Year-round
Marsh harrier *Circus aeruginosus*	364 breeding females (2005)	Year-round
Hen harrier *Circus cyaneus*	Breeding: 11 pairs (2007) Winter: 300 (1986)	Year-round
Montagu's harrier *Circus pygargus*	13 breeding pairs	Breeding
Golden eagle *Aquila chrysaetos*	1 male (2008)	Year-round
Osprey *Pandion halietus*	2 pairs (2008)	Breeding
Merlin *Falco columbarius*	Breeding: 350 pairs (1993-94) Winter: 700 (1990-94)	Year-round
Peregrine falcon *Falco peregrinus*	601 occupied territories (2002)	Year-round
Black grouse *Tetrao tetrix*	1029 displaying males estimated (2008)	Year-round
Common crane *Grus grus*	5 pairs (2008)	Year-round

Table continued...

Species	Population size, England	Season
Stone curlew *Burhinus oedicnemus*	350 pairs (2007)	Breeding
Golden plover *Pluvialis apricaria*	Breeding: 6,000 pairs (2007) Winter: 134,000 (1999-2004)	Year-round
Lapwing *Vanellus vanellus*	Breeding: 61,000 pairs estimated (1998) Winter: 1,000,000 (1981-92)	Year-round
Dunlin *Calidris alpina schinzii*	Breeding: 600 pairs (2005)	Breeding
Sandwich tern *Sterna sandivensis*	9,018 pairs (1998-2002)	Breeding and passage
Roseate tern *Sterna dougallii*	76 pairs (2004)	Breeding
Common tern *Sterna hirundo*	4, 850 pairs (2004)	Breeding
Arctic tern *Sterna paradisaea*	3 602 pairs (1998-2002)	Breeding
Little tern *Sterna albifrons*	1,541 pairs (2004)	Breeding
Nightjar *Caprimulgus europaeus*	4,282 churring males (2004)	Breeding
Chough *Pyrrhocorax pyrrhocorax*	2 pairs (2008)	Year-round

Additionally, important populations of all breeding and wintering wildfowl, waders and seabirds are likely to require detailed assessments.

Appendix 2: case study - COLDHAM WIND FARM, MARCH, CAMBRIDGESHIRE

Coldham Wind Farm currently consists of 8 x 2 MW turbines (100 m tip height) situated amongst arable land in the Cambridgeshire Fens, close to the town of March. Post-construction monitoring was carried out by consultants from Bioscan UK, between October 2006 and October 2007 in order to inform proposals to extend the windfarm.

Methods

The primary objective of the surveys was to quantify the collision risk of birds and bats with the existing turbines. Weekly searches were made over a minimum 60 m distance from each turbine base, with surveyors slowly walking a pattern of approximately 2 m transects. This took from between 45 minutes (winter) to 3 hours (summer) depending on the growth of crops beneath the turbines. On discovery of a corpse, various data were collected such as: species; sex and age (where possible); condition; distance from turbine base; habitat; and likelihood of death being caused by collision. Photos were taken in-situ and corpses were left on the site in an attempt to calibrate search efficiency and predator removal rates.

Results

A total of 14 different species were found over the course of 46 visits. These were: woodpigeon (17); pheasant (10); kestrel (3); red-legged partridge (3); mallard (2); swift (2); black-headed gull; magpie; mistle thrush; rook; sparrowhawk; starling; stock dove; teal (all single birds). Corpses of larger birds remained for at least two consecutive weeks on all but two occasions, indicating that scavenger removal was generally low for these. The majority of casualties were found between 30 to 49 m from the turbine base, though pheasants were found 0-10 m away due to frequent collision with the tower.

In addition to birds, five bats were located, with a another being found on site by a member of the public. Tests found these all to be 55khz Pipistrelle, apart from a suspected Myotis species that was not seen by the surveyor. Despite surveys being carried out all year, bats were only found between 03/08/07 and 12/10/07.

Analysis and discussion

Tests of surveyor detection rates were made using the bat corpses, due to their small size and cryptic colouration. These tests provided a detection rate of at least 66%. This is relatively high, though scavenger removal rates prior to detection in the field would also need to be estimated to attain a reliable figure for actual collision rates. It was estimated that between 6-12 birds per turbine per year were killed, primarily gamebirds and woodpigeons (67% of individuals found). Excluding these species it was estimated that around 20 birds were killed annually for the 8 turbines present.

The species that appears most at risk is the kestrel, with a significant mortality given the relatively dispersed local population, suggesting the potential for local extinction. Small passerines were notably absent despite large numbers of flocking species being observed on site over-winter (skylark, meadow pipit etc), which may support the assumption that these are at a low risk of collision. There was a strong trend (though not statistically significant) for turbines close to the edge of a small woodland resulting in a higher rate of collision. Over the winter period there appeared to be a relationship between weeks with poor weather conditions (low visibility) and fresh collisions.

The concentration of 55 khz Pipistrelle bat corpses during August to October may indicate that this species is at particular risk due to post-breeding migrational movements. This is interesting, given that 55 khz Pipistrelles are a species currently only thought to be at medium risk from collision. Although Noctules are thought to be a high risk species and are known to be present in the area, including a regionally significant roost in nearby March, no collisions were recorded.