Effects of wind farms on birds

R.H.W. Langston and J.D. Pullan, RSPB/BirdLife

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Executive summary

This report was commissioned by the Council of Europe for the Bern Convention as an update of the one commissioned by them last year and presented to the 22nd meeting of the Standing Committee for information. Its remit is to

> *analyse the impact of windfarms on birds, establishing criteria for their environmental impact assessment and developing guidelines on precautions to be taken when selecting sites for windfarms.*

This revised version has, as an additional annex (Appendix 2), a draft recommendation for consideration by the 23rd meeting of the Standing Committee.

The impact of windfarms on birds

A review of the literature identified the main potential hazards to birds from windfarms to be:

- disturbance leading to displacement or exclusion, including barriers to movement;
- collision mortality;
- loss of, or damage to, habitat resulting from wind turbines and associated infrastructure.

There have been few comprehensive studies, and even fewer published, peer-reviewed scientific papers. Many studies suffer from a lack of before and after, or windfarm area and reference area comparisons, or a total lack of assessment of relevant factors such as collision/collision risk, differences in bird behaviour between night and day, or are of inadequate duration to provide conclusive results. In some cases, the reason for the short timescale is that studies are in their early stages and so there may be further information available in future.

It is clear that there is a need for robust, objective baseline studies to inform sensitive siting to minimise deleterious effects on birds, other wildlife and their habitats, and a need for post construction monitoring at consented installations where there are environmental sensitivities. There is clearly a distinction to be made between effects of a temporary versus a permanent nature. There is also a need to put into context the potential impacts to determine the spatial scales at which they may apply, e.g. site, local, regional, national and/or international.

Disturbance

The effects attributable to windfarms are variable and are species-, season- and site-specific. Disturbance can lead to displacement and exclusion from areas of suitable habitat, effectively loss of habitat for the birds.

There are several reliable studies indicating negative effects up to 600 m from wind turbines, i.e. a reduction in bird use of, or absence from, the area close to the turbines, for some species (eg whooper swan *Cygnus Cygnus*, pink-footed goose *Anser brachyrhynchus*, European white-fronted goose *A. albifrons*, Eurasian curlew *Numenius arquata*). In a large windfarm, even this relatively small exclusion area around an individual turbine may amount to a cumulatively significant exclusion area, or area of reduced use, even within a single windfarm.

The scale of such habitat loss, together with the extent of availability and quality of other suitable habitats that can accommodate displaced birds, and the conservation status of those birds, will determine whether or not there is an adverse impact.

Habituation may occur, cf. observed differences in behaviour between residents and migrants in some studies, but studies over several years of eagles in California provide little indication of habituation and few other studies have been of long enough duration to demonstrate whether or not habituation occurs.

Disturbance potentially may arise from increased human activity in the vicinity of the windfarms, e.g. during construction, maintenance visits, facilitation of access via access roads, often in areas of little human activity before the arrival of a windfarm. The presence/noise of turbines may also deter birds from using the area close to turbines. Few studies are conclusive in their findings, often because of a lack of well-designed studies both before and after construction of the windfarm. Furthermore, very few studies take account of differences in diurnal and nocturnal behaviour, basing assessments on daytime only, which is inadequate for those species which are active during darkness and which may behave differently at night compared with during the day.

There is some indication that wind turbines may be barriers to bird movement. Instead of flying between the turbines, birds may fly around the outside of the cluster. Whether this is a problem will depend on the size of windfarm, spacing of turbines, the extent of displacement of flying birds and their ability to compensate for increased energy expenditure. The cumulative effects of large windfarm installations may be considerable if bird movements are consequently displaced. This may lead to the disruption of ecological links between feeding, breeding and roosting areas.

Windfarm design may alleviate any barrier effect, for example allowing wide corridors between clusters of turbines. Research and post-construction monitoring at several pilot sites will be necessary to determine whether and where this is an acceptable solution.

The wind energy industry is in its infancy offshore and, consequently, there has been little research into the impacts on birds. Nonetheless, there are useful studies underway, especially in The Netherlands and Denmark, indicating a variable response that is both site- and species- specific, just as onshore. The proposals for large windfarms in shallow sea areas may conflict with the feeding distributions of seabirds, notably seaducks, if these are displaced due to disturbance and consequently excluded from their main feeding areas. The potential cumulative effects of multiple installations are a particular concern.

Collision risk and mortality

The majority of studies have quoted low collision mortality rates per turbine, but in many cases these are based only on found corpses, leading to under-recording the actual number of collisions. Even where collision rates per turbine are low, this does not necessarily mean that collision mortality is insignificant, especially in windfarms comprising perhaps several hundreds or thousands of turbines. Even relatively small increases in mortality rates may be significant for populations of some birds, especially large, long-lived species with generally low annual productivity and slow maturity, notably so when already rare.

Relatively high collision mortality rates have been recorded at several large, poorly sited windfarms in areas where large concentrations of birds are present (including Important Bird Areas (IBAs)), especially migrating birds, large raptors or other large soaring species, e.g. Altamont Pass in California, USA, Tarifa and Navarra in Spain. In these cases, actual deaths resulting from collision are high, notably of golden eagle *Aquila chrysaetos* and griffon vulture *Gyps fulvus*, respectively.

Collision mortality at poorly sited windfarms may have population level effects, and cumulative mortality from multiple wind installations may also contribute to population decline in susceptible species. Making projections of the potential magnitude of wind turbine-related avian fatalities is problematic because of the frequent lack of objective information.

The weight of evidence to date indicates that locations with high bird use, especially by species of conservation concern, are not suitable for windfarm development (e.g. in Spain, regional recovery plans prohibit windfarms in areas important for breeding and feeding imperial eagles *Aquila heliaca*). Site selection is crucial to minimising collision mortality. The precautionary principle is advocated where there are concentrations of species of conservation importance. It is therefore very important that alternative locations are proposed for the potentially most hazardous windfarms.

Wind speed and direction, air temperature and humidity, flight type, distance and height, time of day and topography, all influence the risk of collision, as do species, age, behaviour and stage of the bird's annual cycle. All these factors need to be incorporated in collision risk assessments. Collision risk is greater in poor flying conditions, such as strong winds that affect the birds' ability to control flight manoeuvres, or in rain, fog, and on dark nights when visibility is reduced. In these conditions, the flight height of migrating birds tends to be greatly reduced. Lighting of turbines has the potential to attract birds, especially in bad weather, thereby potentially increasing the risk of collision.

Few studies attempt observations in poor weather and visual observations are limited in such conditions. However, remote techniques can be used to extend observations beyond the visible spectrum, e.g. radar, thermal imagery and, at the very least predictions of the likely frequency of the weather conditions that increase collision risk can be used to inform the risk assessment.

Most studies have been of small turbines, often in small clusters; the implications of newer, larger turbines and larger windfarms may be different. The importance of windfarm location and layout in determining the risk of collision by birds with wind turbines is apparent from studies both onshore and offshore.

Collision mortality arises as a result of collision with turbines, meteorological masts and powerlines. Thus, assessment of bird collision risk and mortality, arising from collision or electrocution, needs to include wind turbines and associated structures, including overhead powerlines transporting energy from the windfarm. It is recognised that the actual rate of collision is likely to be under-recorded, owing to the limitations of the study techniques, particularly corpse searches, so it is essential that calibration is undertaken at each site to enable correction factors to be applied to produce more realistic estimates of collision mortality.

Collision risk models provide a potentially useful means of predicting the scale of collision attributable to wind turbines in a given location, but only if they incorporate actual avoidance rates in response to fixed structures and post-construction assessment of collision risk at windfarms that do proceed, to verify the models. Population models provide a means of predicting whether or not there are likely to be population level impacts arising from collision mortality. Again, they require post-construction verification at consented windfarms to test the validity of the predictions and the models.

Habitat loss or damage

Loss of or damage to habitat, resulting from windfarm infrastructure, is not generally perceived to be a major concern for birds outside designated or qualifying sites of national and international importance for biodiversity, depending on local circumstances and the scale of land-take required for the windfarm and associated infrastructure. The cumulative loss of or damage to sensitive habitats may be significant, especially if multiple, large developments are sited in such locations, e.g. on sandbanks in shallow waters or on peatlands. Furthermore, direct habitat loss may be additive to disturbance exclusion.

Onshore infrastructure including turbine bases, substations and access roads etc will involve direct habitat loss. This is generally fairly small scale, but could affect local hydrology in sensitive habitats and, again, the effects will depend on the size of the windfarm and especially the extent of any road network required.

Offshore, direct habitat loss is generally small-scale, primarily for turbine bases and cables at sea. However, increasingly large windfarms, especially on feeding areas such as sandbanks in shallow waters, may give cause for concern and habitat change or damage may be significant.

Other issues

Turbines may offer roosting or nesting sites for birds. However, research needs to be undertaken to assess the extent of bird use. In the offshore environment, there may be adverse effects on birds as a result of disruption to, or encouragement (collision risk for birds feeding among turbines) of, avian food resources such as benthos and fish populations, for example as a consequence of the effects of electromagnetic fields around under-sea power cables. These aspects require further study to clarify whether or not there are significant issues of concern.

Environmental assessment and site selection guidelines

Criteria for Environmental Assessment

All windfarm developments require screening and those that have the potential for damaging effects on wild birds or the wider environment, or in areas where there is uncertainty as to the potential effects, require a robust environmental impact assessment (EIA[1]). This needs to include comprehensive environmental impact assessment for individual projects and an assessment of the cumulative impacts arising from each windfarm proposal (including associated infrastructure onshore and offshore, such as new roads, powerlines and under-sea cabling) in conjunction with other projects (both other windfarms and other relevant projects).

There is considerable support for wind energy as an environmentally benign source of energy. Nonetheless, stringent environmental assessment is just as important for wind energy as for other developments to ensure that it is sited optimally and to avoid or at least minimise any adverse impacts. Poor quality EIAs, or lack of information, must not be permitted to lead to planning approval on the grounds of no demonstrable effect.

Standardised study methods, to ensure comparability, are essential, as is consistency in their application before, during and after construction, in the windfarm area and a reference area (BACI - Before-After Control-Impact). It is recommended that a minimum one-year baseline field study should be undertaken to determine the use of the study-area by birds and to identify which, if any, species may be adversely affected by windfarm construction. Post-construction monitoring needs to enable short- and long-term effects and impacts to be distinguished and provide the information to enable them to be satisfactorily addressed.

On the basis of the literature review, species' conservation status and more than 10 years collective experience by the BirdLife partners, the following species groups and example species are considered to be particularly sensitive, or potentially so, to

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[1] In EU states, by reference to the selection criteria set out in Article III of Directive 85/337/EEC on the *'Assessment of certain public and private projects on the environment'*, as amended by Directive (97/11/EC), or the use of similar criteria in countries where this is inappropriate.

windfarm (disturbance displacement, barriers to movement, collision, habitat loss or damage), although in many cases there is a lack of impact studies to date. Thus, they are likely to be focal species for detailed environmental assessment and research. This list is indicative rather than comprehensive. There are many species for which there is either no information, or no conclusive information, to date. Focal species are likely to be site and issue specific and may change in the light of further research or change in conservation status.

Species group (eg species)	**Disturbance displacement**	**Barrier to movement**	**Collision**	**Direct habitat loss/damage**
Gaviidae, divers (red-throated diver *Gavia stellata*)	√	√	√	
Podicipedidae grebes	√			
Sulidae gannets & boobies			√	
Phalacrocoracidae (shag *Phalacrocorax aristotelis*)				√
Ciconiiformes herons & storks			√	
Anserini, swans (whooper swan *Cygnus cygnus*) and geese (pink-footed goose *Anser brachyrhynchus*, European white-fronted goose *A. albifrons*, barnacle goose *Branta leucopsis*, brent goose *B. bernicla*)	√		√	
Anatinae, ducks (eider *Somateria mollissima*, long-tailed duck *Clangula hyemelis*, common scoter *Melanitta nigra*)	√	√	√	√
Accipitridae raptors (red kite *Milvus milvus*, white-tailed sea eagle *Haliaeetus albicilla*, lammergeier *Gypaetus barbatus*, griffon vulture *Gyps fulvus*, imperial eagle *Aquila heliaca*, golden eagle *A. chrysaetos*, Bonelli's eagle *Hieraetus fasciatus*)	√		√	
Charadriiformes waders (European golden plover *Pluvialis apricaria*, black-tailed godwit *Limosa limosa*, Eurasian curlew *Numenius arquata*)	√	√		
Sternidae terns			√	
Alcidae alcids/auks (guillemot *Uria aalge*)	√		√	√
Strigiformes owls			√	
Tetraonidae (black grouse *Tetrao tetrix*, capercaillie *T. urogallus*)	√		√	√
Gruidae cranes	√	√	√	
Otididae bustards	√		√	√
Passeriformes especially nocturnal migrants			√	

Precautions for site selection of windfarms

There is a strong consensus that location is critically important to avoid deleterious impacts of windfarms on birds. There should be precautionary avoidance of locating windfarms in statutorily designated or qualifying international (e.g. Natura 2000 – SPAs & SACs, 'Ramsar sites', Emerald Network and Important Bird Areas (IBAs)) or national sites for nature conservation, or other areas with large concentrations of birds, such as migration crossing points, or species identified as being of conservation concern. The favourable conservation status of habitats and species in these areas is a central tenet to their designation, requiring demonstration of compatibility with this aim by any proposed development. The weight of evidence to date indicates that locations with high bird use, especially by protected species, are not suitable for windfarm development.

Adverse impacts on wildlife must be avoided by full evaluation of suitable alternatives, appropriate siting and design.

Recommendations

There is an urgent need for statutory marine protected areas to be identified and designated.

Research and monitoring should be implemented by national governments and the wind energy industry, in consultation with relevant experts, to improve our understanding of the impacts of windfarms. This will be an iterative process that will inform decision-making, appropriate site selection and windfarm design. The results of research should be published in international scientific journals, including a summary, preferably in English, to ensure wider dissemination.

Research and monitoring requirements encompass the following: effects and potential population level impacts on birds of disturbance displacement, barriers to movement, collision mortality and habitat loss or damage; effectiveness of different windfarm layout and turbine design to provide mitigation.

National governments must undertake Strategic Environmental Assessment (SEA)[1] of all wind energy plans and programmes that have the potential for an adverse effect on wildlife in their country. If there are potential trans-boundary effects, then international co-operation with other governments should be sought when undertaking the SEA. The scale of SEA should be determined by consideration of the likely biological scale of impacts as well as jurisdictional boundaries.

Specifically, these SEAs should include indicative mapping of bird populations, their habitats, flyways and migration routes and an assessment of the plan's probable effects on these, to aid decision-making.

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[1] As set out in Directive 2001/42/EC of the European Parliament and of the Council, 27 June 2001 '*on the assessment of the effects of certain plans and programmes on the environment'*.

As part of effective regional planning, there is a need to identify species and areas of concern, to map potential and no-go locations for wind energy development on the basis of nature conservation concerns, for example avoidance of focal points for migration crossings. This may require the collection of additional information, especially offshore.

There need to be incentives to ongoing technological development to maximise efficiency of wind turbines and to reduce dependency on the limited shallow water habitats offshore.

There is a need for best practice guidance on standard study methods, to inform the EIA process.

This report has not looked in detail at individual case studies to evaluate examples of conflict resolution, case law, or trends in casework throughout the Council of Europe area. This may be a useful subject for further study.

Glossary

Auto-ecology	Study of the relationship between a single species and its environment.
BACI	Before-After Control Impact study combines data collection before and after, in this case construction of a windfarm, on both the proposed development site and at least one reference (or control) site. The latter should be as comparable as possible to the proposed development site to enable the distinction of any observed changes that are attributable to the windfarm (e.g. Anderson *et al.* 1999).
COWRIE	Collaborative Offshore Wind Research Into the Environment. A UK forum, led by The Crown Estate and involving government, wind energy industry and non-government conservation bodies. Established to prioritise and commission environmental research into windfarms.
Emerald Network	Network of Areas of Special Conservation Interest (ASCIs), designated under the Bern Convention. In the EU, Natura 2000 sites are part of the Emerald Network.
Important Bird Area (IBA)	Area identified by BirdLife International in their European IBA programme as being of international importance for birds (Heath & Evans 2000).
Installed capacity	The generating capacity of all completed and active turbines.
Nacelle	Casing housing the turbine gears and generator, attached to the rotor blades.
Natura 2000 Network	Network of SPAs and SACs as designated under Directives 79/409/EEC and 92/43/EEC.
Monopile	Single foundation rod pile-driven into the ground/seabed.
OSPAR	OSPAR Convention, signed in 1992, is the legal framework for the protection of the marine environment of the North Atlantic, developed from the Oslo and Paris Conventions set up to prevent marine pollution.

Precautionary principle	This stipulates that where a potentially damaging effect cannot be quantified with sufficient certainty, decision makers should err on the side of caution.
Special Protection Area (SPA)	International site within the European Union, designated under Directive 79/409/EEC on the Conservation of Wild Birds.
Special Area of Conservation (SAC)	International site within the European Union, designated under Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna.
‘Ramsar’ site	International site, designated under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran 1971).
Reference site	See BACI above. A reference site that is not subject to a windfarm proposal, but otherwise is highly comparable to the proposed windfarm site, provides a comparison with studies on the windfarm site. Given the limited control over variables in the real world (as opposed to laboratory conditions), such a site is not strictly a control (in which variables are held constant), hence the term reference site.
Statutory site	A site that is protected by either national or international law.

1. Introduction

Most commentators and governments now accept that climate change is a reality, with all of its attendant risks to our way of life and the environment. Renewable sources of energy offer an opportunity to minimise the deleterious environmental changes of climate change, arising from over-reliance on fossil fuels. Of the most advanced renewable technologies, wind energy is set to make a substantial contribution to energy generation in the countries to which the Bern Convention applies. By the end of 2001, 4500 MW of wind power capacity was added to the European electricity grids, bringing the installed capacity (as distinct from energy output) from wind in Europe to more than 17000 MW. Germany, Denmark and Spain currently lead the way in installed capacity from wind energy.

Most of this installed capacity is at present from onshore facilities. However, with developments in technology, offshore windfarms are likely to make up a significant part of future windfarm development in Europe – for example, the UK government announced a major initiative to stimulate offshore wind development in July 2003. Whilst there are few operational offshore windfarms at present in Europe, there are many more applied for or authorised for construction and still more in the planning stages (OSPAR windfarms database, unpublished). It is essential that robust assessment of potential environmental impacts, notably on biodiversity[1] and habitats, becomes an integral part of the planning process to inform sensitive siting and so avoid deleterious environmental impacts.

This report first presents a review of the literature (published and unpublished) that documents the findings of research into bird - windfarm interactions at both onshore and offshore windfarms, together with recommendations derived from those studies. The review is organised into sections dealing with the issues of:

- disturbance leading to displacement or exclusion, including barrier effects,
- collision mortality,
- loss of or damage to habitat resulting from wind turbines and associated infrastructure; and
- other potential effects.

The report then gives guidance on:

- criteria for assessing environmental impacts of windfarms on birds; and
- precautions to be taken when selecting sites for windfarms.

This guidance is the result of more than 10 years of experience from BirdLife International and its European Partners, regarding the compatibility of windfarms with bird populations and habitats, and has taken into account the literature that documents the findings of research into bird - windfarm interactions at both onshore and offshore windfarms. Offshore wind energy is at an earlier stage of development and whilst there are many transferable aspects of the results of onshore studies to the

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[1] See Convention on Biological Diversity www.biodiv.org/doc/publications/guide.asp

offshore environment, there are also some distinctive differences, hence the separation in the following review. Supporting information to the guidance is presented in Annex I, together with summarised information on study protocols, which was not formally sought for the commissioned report, but which was considered by the authors to be a useful addition. It is hoped that this material will provide helpful pointers to readers.

2. Review of the literature on the impacts of windfarms on birds

The purpose of this section of the report is to provide a summary (updated from that in the September 2002 draft of this report) of the literature relating to impacts of windfarms on birds, drawing principally on English language literature (see list of references at the end of the review). Although including references to the most useful and relevant studies up to 1996, it concentrates mainly on subsequent work (especially for offshore windfarms) to information included in these earlier recommended reviews:

- Crockford, N.J. (1992) *A review of the possible impacts of windfarms on birds and other wildlife*. JNCC Report 27. Peterborough. Joint Nature Conservation Committee;
- Gill, J.P., Townsley, M. & Mudge, G.P. (1996) *Review of the impacts of windfarms and other aerial structures upon birds.* Scottish Natural Heritage Review No. 21;
- SGS Environment (1996) *A review of the impacts of windfarms on birds in the UK.* ETSU W/13/00426/REP/1,2,3.

The three review reports listed above, together with the review of literature that follows, provide a fairly comprehensive review of the literature available up to early 2003, from principally English language documentation.

The emphasis of this review is studies of bird - windfarm interactions. The literature indicates that the main potential hazards to birds from windfarms are:

- disturbance leading to displacement or exclusion, including barriers to movement;
- collision mortality;
- loss of or damage to habitat resulting from wind turbines and associated infrastructure.

2.1. Disturbance

2.1.1 Disturbance onshore

– *Summary*

This section considers the effects of onshore windfarms, including coastal locations, on breeding, feeding and roosting birds.

The effects attributable to windfarms are variable and are species-, season- and site-specific. Disturbance can lead to displacement and exclusion from areas of suitable habitat, effectively loss of habitat for the birds.

There are several reliable studies indicating negative effects up to 600 m from wind turbines, i.e. a reduction in bird use of, or absence from, the area close to the turbines, for some species (e.g. whooper swan *Cygnus Cygnus*, pink-footed goose *Anser brachyrhynchus*, European white-fronted goose *A. albifrons*, Eurasian curlew *Numenius arquata*). In a large windfarm, even this relatively small exclusion area around an individual turbine, may amount to a cumulatively significant exclusion area, or area of reduced use, even within a single windfarm.

The scale of such habitat loss, together with the extent of availability and quality of other suitable habitats that can accommodate displaced birds, and the conservation status of those birds, will determine whether or not there is an adverse impact.

Habituation may occur, ref. observed differences in behaviour between residents and migrants in some studies, but studies over several years of eagles in California provide little indication of habituation and few other studies have been of long enough duration to demonstrate whether or not habituation occurs.

Disturbance potentially may arise from increased human activity in the vicinity of the windfarms, e.g. during construction, maintenance visits, facilitation of access via access roads, often in areas of little human activity before the arrival of a windfarm. The presence/noise of turbines may also deter birds from using the area close to turbines. Few studies are conclusive in their findings, often because of a lack of well-designed studies both before and after construction of the windfarm. Furthermore, very few studies take account of differences in diurnal and nocturnal behaviour, basing assessments on daytime only, which is inadequate for those species which are active during darkness and which may behave differently at night compared with during the day.

– Breeding birds

Winkelman's studies at Oosterbierum, in The Netherlands (1992d), investigated the effects on numbers and distribution of breeding birds with increasing distance from the wind turbines, but found no effect on Eurasian oystercatcher *Haematopus ostralegus,* northern lapwing *Vanellus vanellus,* black-tailed godwit *Limosa limosa* or common redshank *Tringa totanus*. These are all long-lived and highly site-faithful species and thus their attachment to a location may outweigh any potential response to change. On the other hand, shorter-lived species with a more rapid turnover of individuals or species that are less site-faithful may display different responses to change, and consequently settlement patterns, so caution is advised in interpreting these results, as with the following studies in Germany and Scotland.

German studies indicate that response to the installation of turbines is species-specific (Ketzenberg *et al.* 2002) and highlight the need for standardised methods to be applied before and after windfarm construction, on both the windfarm area and a reference area. Specifically, this study investigated the breeding densities and spatial distribution of common skylark *Alauda arvensis* and several species of breeding waders (Eurasian oystercatcher, northern lapwing, common redshank and black-tailed godwit), before and after installation of windfarms in four coastal areas in Lower Saxony. Changes in total breeding pairs following construction were not consistent, with some increases and some decreases. In some cases numbers of breeding waders increased near wind turbines because of the alteration to farming practice post-construction, emphasising the need to consider other changes contemporary with the windfarm development. The implication is that, at least for some species, habitat quality outweighs any negative effect of turbines. No effect on numbers or spatial distribution of Eurasian oystercatcher, northern lapwing and common skylark was observed within 1km, but negative effects were observed for common redshank and black-tailed godwits within 200 m of the turbines.

Studies at the Dun Law windfarm, in Scotland (Gill 2000a & b) compared the breeding bird populations in the windfarm area plus 800 m buffer and a broadly comparable reference area, using moorland bird survey methodology (Brown & Shepherd 1993). The surveys to date provide baseline information prior to construction and information from the partially constructed windfarm, and form the early part of a study of several years' duration. Breeding waders showed similar between-year changes in numbers on both windfarm and reference areas (Gill 2000b). Unfortunately, for unknown reasons, the buffer was reduced to 250 m in the 2000 survey, and resulted in the reduction in the number of breeding Eurasian curlews recorded in the study area. This emphasises the need for consistency in survey methods and it is not clear whether there are any implications of turbine location in the distribution of breeding Eurasian curlews observed in 2000. Generally, the observations indicated that breeding waders were not disturbed by the presence of turbines, but see cautionary note in earlier paragraph (2.10); it is not clear whether turbines might deter settlement by new recruits to the wader breeding population.

At Windy Standard windfarm in Dumfries and Galloway, in the UK, breeding bird surveys (Moorland Bird Survey method, Brown & Shepherd 1993) were carried out before, during and after construction, amounting to 7 years of monitoring data (DH Ecological Consultancy 2000a). The main species recorded were meadow pipit *Anthus pratensis,* common skylark and red grouse *Lagopus lagopus scoticus* and no demonstrable effects were detected on these species (DH Ecological Consultancy 2000b).

At Burgar Hill, on Orkney, Scotland, studies of distance effects in relation to the 3-turbine wind cluster, found no significant difference in numbers of breeding pairs of ducks *Anatidae,* waders *Charadriiformes*, Arctic (parasitic) skua *Stercorarius parasiticus,* gulls *Laridae* and small passerines, between the year of installation and the subsequent 8 years (Meek *et al.* 1993). However, breeding numbers of red-throated diver *Gavia stellata* did decline as a result of disturbance during construction. The sample size was small (there were 5 pairs of divers at the start of the study, declining to 2 pairs), requiring caution in interpreting the biological significance of the results. This is often a difficulty with individually small, piecemeal developments, but the comparative assessment of several similar studies will provide a measure of the consistency of the response.

Thomas (1999) undertook a study of 10 upland windfarms in the UK, comparing breeding bird distributions (Moorland Bird Survey method, Brown & Shepherd 1993) at windfarm sites with their respective reference sites, and in relation to Phase 1 habitat data. Most of these studies were of small wind clusters, comprising small turbines and individually produced small sample sizes. However, consideration of these studies collectively provides a measure of the direction of observed changes. To compensate for the lack of before and after (construction) data, random points were generated to compare with actual bird distributions in relation to turbine locations. The study is limited by there being only one survey visit to each site and differences between some reference sites and the windfarm site in terms of habitat composition. These shortcomings have to be borne in mind when considering the findings:

- Overall bird densities at windfarm sites were not significantly lower than on reference sites.
- There were no significant differences between densities on windfarm sites and reference sites for common skylark or meadow pipit, the only species sufficiently numerous to enable statistical comparison, although there were some site-specific differences.
- There was no evidence of clumped distributions of breeding birds and no significant difference in the extent of clustering between windfarm sites and reference sites, i.e. the spatial distribution of breeding birds was comparable both between and within windfarm sites and reference sites.
- Taller wind turbines, longer rotor blades (although limited variation in blade lengths studied), and larger windfarms were not associated with lower bird densities, suggesting that there was no greater avoidance of larger turbines over smaller ones within the limited size range studied.
- Northern lapwing and Eurasian curlew were the only wader species sufficiently numerous (and still numbers were small at individual study sites) to enable an assessment of their proximity to wind turbines across all the study sites. Northern lapwing nests occurred slightly closer to the turbines than predicted (but see Ketzenberg *et al.* 2002). Avoidance of wind turbines from combined species data was observed at only one of the ten study sites.

Studies at Buffalo Ridge, Minnesota, USA (Leddy *et al.* 1999) found increased densities of breeding grassland passerines with increased distance from wind turbines in the windfarm area, and higher densities in the reference areas than within 80 m of the wind turbines. They did not find an effect of operational versus non-operational turbines, indicating that the presence of turbines had some deterrent effect, although it is unknown whether the effect was long-lasting.

– Feeding and roosting birds

In The Netherlands, variable levels of disturbance have been apparent for feeding and roosting birds (Spaans *et al.* 1998a). At Oosterbierum, Winkelman (1992a) found significantly smaller numbers of feeding and roosting birds within the windfarm and surrounding area when the turbines were operational, with effects observed up to 500 m from wind turbines for Eurasian curlew. Other species affected to differing distances were mallard *Anas platyrhynchos,* tufted duck *Aythya fuligula,* Eurasian oystercatcher, European golden plover *Pluvialis apricaria,* Eurasian coot *Fulica atra,* northern lapwing, common gull *Larus canus* and herring gull *Larus argentatus.* During construction and partial operation, similar effects were observed for all but mallard, Eurasian oystercatcher and common gull. In addition, no disturbance effects were demonstrated for black-headed gull *Larus ridibundus,* common starling *Sturnus vulgaris* or crows *Corvidae*. However, it was not possible to separate the effects of the windfarm from any other contemporary changes in the absence of a reference area, which limits the usefulness of this study.

Studies at Urk, The Netherlands (Winkelman 1989) found decreases within the windfarm area in winter, which extended to 300 m away from the windfarm, for mallard, tufted duck, common pochard *Aythya ferina* and common goldeneye *Bucephala clangula.* There was little or no effect on great-crested grebe *(Podiceps cristatus,* Eurasian coot, common gull, or gulls combined and increased numbers of black-headed gull and greater scaup *Aythya marila* in the windfarm area. Most results for swans and geese were inconclusive, except for whooper swan *Cygnus cygnus*, which decreased in one year of the study. The results were confounded by severe weather in the year prior to construction, followed by two mild winters post-construction. However, studies at Overgaard, in Denmark, estimated effective proportionate loss of habitat amounting to 1-2.5% of the area previously used by feeding whooper swans due to disturbance displacement by turbines (Larsen & Clausen 1998, Clausen & Larsen 1999).

Avoidance behaviour by pink-footed geese *Anser brachyrhynchus* in relation to a suite of physical landscape variables, including wind turbines, was studied in Denmark (Larsen & Madsen 2000). The authors observed an interesting difference in avoidance behaviour in response to windfarm layout and indicated a cumulative effect of additional windfarms in reducing the habitat available to feeding geese. The avoidance distance in response to windfarm layouts in lines and in clusters were ca 100 m and ca 200 m respectively and geese did not enter the area between turbines arranged in a cluster. Linear arrays of wind turbines tended to be sited alongside roads or other features already avoided (e.g. Gill *et al.* 1996), whereas wind clusters tended to be sited on open farmland.

Avoidance behaviour by European white-fronted geese *Anser albifrons* was more marked in response to the Rheiderland windfarm in Germany (Kruckenberg & Jaene 1999). In studies before and after construction of the windfarm, on the windfarm site and a reference area, substantially lower densities of feeding geese were found within 600 m of the wind turbines.

Blyth Harbour windfarm, in the UK, is sited in a commercial harbour in an industrial area, and comprises nine turbines (300 kW) built at 200 m intervals along the estuary's breakwater (Still *et al.* 1996). The breakwater is a Site of Special Scientific Interest, under the UK 1981 Wildlife and Countryside Act, because it hosts a large winter roost of purple sandpipers *Calidris maritima,* and the estuary it protects adjoins an SPA and a Ramsar site. The estuary supports a relatively high density of birds. During peak periods, up to ca 5000 bird movements a day occur adjacent to the windfarm. Counts of all bird species were undertaken before construction (Dec. 1991-July 1992), during construction (Aug 1992-Jan 1993) and the early phase of operation (January 1993-July 1995). Great cormorants *Phalacrocorax carbo* were temporarily displaced from their roost during construction, but returned once the windfarm was operational. No displacement was reported for the other species studied. Numbers of great cormorant, common eider *Somateria mollissima,* purple sandpiper and gulls (the species for which any comparison was made) remained comparable after construction.

Research findings, such as those included in the above review of the literature, have been incorporated in the decision making process. There are two recent examples of German case law leading to the refusal of windfarms in IBAs, on the basis of the risk of disturbance, leading to avoidance of turbines by staging geese, (Elbe, on appeal in 2000, & Leybucht, H. Hötker pers. comm.).

Differences in nocturnal and diurnal bird behaviour have not been taken into account in the majority of studies, an important omission in assessing site use and the potential effects of proposed windfarm development. Work in Germany by Ketzenberg & Exo (1997), involving radio-tracking of individual European golden plovers, demonstrated differences in feeding locations during the night from those utilised during daylight and, hence, have potentially different implications for siting windfarms.

2.1.2 Disturbance offshore

– Summary

This section considers the effects of offshore windfarms on birds.

The wind energy industry is in its infancy offshore and, consequently, there has been little research into the impacts on birds. Nonetheless, there are useful studies underway, especially in The Netherlands and Denmark, indicating a variable response that is both site- and species- specific, just as onshore. The proposals for large windfarms in shallow sea areas may conflict with the feeding distributions of seabirds, notably seaducks, if these are displaced due to disturbance and consequently excluded from their main feeding areas. The potential cumulative effects of multiple installations are a particular concern. Habituation may occur, but few studies have been of long enough duration to demonstrate whether or not habituation occurs.

There is some indication that wind turbines may be barriers to bird movement. Instead of flying between the turbines, they may fly around the outside of the cluster. Whether this is a problem will depend on the size of windfarm, spacing of turbines, the extent of displacement of flying birds and their ability to compensate for increased energy expenditure. The cumulative effects of large windfarm installations may be considerable if bird movements are consequently displaced. This may lead to the disruption of ecological links between feeding, breeding and roosting areas.

Windfarm design may alleviate any barrier effect, for example allowing wide corridors between clusters of turbines. Research and post-construction monitoring at several pilot sites will be necessary to determine whether and where this is an acceptable solution.

The first offshore windfarm was built in 1990, 250 m off the coast at Nogersund in Sweden (Larsson 1994). In view of the large numbers of migrants passing along this coast, pre- and post-construction data on bird movements were recorded in different distance bands from the coast. The majority of records were below an altitude of 50 m. Post-construction reductions in the numbers passing within 500m of the coast were noted, with many species tending to fly further out from the coast and around the outside of the windfarm.

In southern Sweden, in the Kalmarsund between the Isle of Öland and the mainland, 7 wind turbines were built in 2000. The total height of the turbines in the Utgrunden windfarm, including the rotors, amounts to 106 m. As the area constitutes a major migration route for large numbers of waterbirds, the permission was linked to a condition to monitor the effect on resting and migrating birds. Such studies started in spring 1998 and were intensified in the year 2001-2002, when field observations and radar studies were performed (Pettersson 2001, 2002). The shallow areas exploited by the windfarm traditionally have been used by large numbers (1000 - 2000 individuals) of feeding long-tailed ducks *Clangula hyemalis.* Local movements of primarily long-tailed ducks, and to some extent eiders and cormorants, that feed in shallow water between and near the windfarms, involve flights between the turbines (Pettersson 2002). Although Pettersson (2002) reported a slight reduction in the number of birds using the windfarm area post construction, it is not yet clear whether this is a short- or long-term effect, and whether it is due to the windfarm or food availability.

Guillemette *et al.* 1998 found decreases in the numbers of common eider and common scoter *Melanitta nigra* in late winter, in the windfarm area compared with the reference area, in the two years following construction of the windfarm at Tunø Knob, in Denmark. Changes in size class and biomass of mussels were thought to be the main determinants of the observed changes in feeding distribution. These fluctuate considerably from year to year and so the observed changes were not considered to be attributable to the introduction of wind turbines. Support for this interpretation, at least for common eiders, was found in the third year post-construction, when there were increases in numbers of common eiders and their benthic prey. There remains the possibility of initial avoidance and subsequent habituation as the recovery in bird numbers was least in close proximity to the windfarm and it was not possible to compare the spatial distribution of benthic prey at a fine enough resolution from the results. However, only partial recovery in numbers of common scoters was noted, indicating possible consequent displacement by the wind turbines (Guillemette *et al.* 1999). Unfortunately, no studies were continued in the Ringebjerg Sand reference area in the third post-construction year, which limits the comparative value of the study.

The studies at Tunø Knob were fairly detailed, compared with many other windfarm studies, and used several approaches for the assessment (Before-After Control-Impact studies were undertaken, comprising aerial and ground surveys, benthos sampling, post-construction experiments including positioning decoys at different distances from the windfarm), although the authors themselves point out various limitations to the work:

- No data were collected on bird collision risk pre-construction nor collisions post-construction. In view of the frequency of foggy conditions in Danish waters, this is an important omission since conditions of poor visibility are associated with collision risk (see section 2B on Collision Risk and Mortality) and the authors advocated the use of radar to enable assessment of collisions in poor weather conditions.
- The experimental results were gathered for small flocks that have been observed to be less sensitive to disturbance than large flocks.
- These studies considered mainly common eiders and therefore may not apply to other (seaduck) species. In particular, the results for common scoters were not conclusive, but indicate a possible disturbance effect.
- These studies were confined to late winter and so do not apply to different seasons and stages of the life cycle; moulting flocks are likely to be more sensitive to disturbance as they are flightless and more vulnerable to predation during moult of the flight feathers.
- Potential disturbance arising from increased boat traffic associated with construction and maintenance was not assessed in this study.
- This study was of a small windfarm, comprising 10 small turbines and so the results may not have wider applicability to larger wind clusters or larger turbines.

Most common eiders and common scoters were observed ≤10 km from the coast during the 2.5 years of baseline surveys for the proposed windfarm at Horns Rev, Denmark (Noer *et al.* 2000, Christensen *et al.* 2001, 2002), and were closely associated with shallow waters ≤6 m deep. The species recorded in sizeable numbers further offshore were piscivores – divers/loons *Gaviidae,* northern gannets *Morus bassanus,* auks *Alcidae,* terns *Sternidae* and gulls, often concentrated around fishing vessels. The distribution of these species was very variable, probably because of the temporal and spatial variability of their fish prey, but generally comparable with records going back to 1963 (Christensen *et al.* 2002). Preference analysis indicated that the proportion of birds recorded in the windfarm area was no more nor less than expected on the basis of the proportion of the study area that it comprised. The worst-case scenario of avoidance of the windfarm plus 4 km buffer, was estimated to affect 8-11% of common scoters (Christensen *et al.* 2002). Cable-laying outside the moult period for common scoters (July-September) was recommended to minimise disturbance to these birds. Both divers and scoters are particularly sensitive to disturbance, e.g. from approaching ships, and tend to occur mainly in marine areas with light sea traffic (Mitschke *et al.* 2001, cited in Exo *et al.* 2002). Construction of the Horns Rev windfarm was completed in summer 2002, and will be the subject of post-construction monitoring which will determine whether there are impacts on birds attributable to the windfarm, including whether avoidance predictions were correct). This windfarm of *ca* 80 turbines (150 MW) is located 14 km offshore, in waters 6.5-13.5 m deep.

2.2 Collision risk and mortality

2.2.1 Collision risk and mortality onshore

– Summary

This section considers collision risk from onshore, including coastal, windfarms. Broadly, the review assesses information from behavioural observations and from corpse searches. The implications of collision mortality for populations of birds of particular conservation concern has led to the development of computed population models to assist in risk assessment. Such models are discussed briefly here.

The majority of studies have quoted low collision mortality rates per turbine, but in many cases these are based only on found corpses, leading to under-recording of the actual number of collisions. Even where collision rates per turbine are low, this does not necessarily mean that collision mortality is insignificant, especially in windfarms comprising perhaps several hundreds or thousands of turbines. Even relatively small increases in mortality rates may be significant for populations of some birds, especially large, long-lived species with generally low annual productivity and slow maturity, notably so when already rare.

Relatively high collision mortality rates have been recorded at several large, poorly sited windfarms in areas where large concentrations of birds are present (including IBAs), especially migrating birds, large raptors or other large soaring species, e.g. Altamont Pass in California, USA, Tarifa and Navarra in Spain. In these cases actual deaths resulting from collision are high, notably of golden eagle *Aquila chrysaetos*, and griffon vulture *Gyps fulvus*, respectively.

Collision mortality at poorly sited windfarms may have population level effects, and cumulative mortality from multiple wind installations may also contribute to population declines in susceptible species. Making projections of the potential magnitude of wind turbine-related avian fatalities is problematic because of the frequent lack of objective information.

The weight of evidence to date indicates that locations with high bird use, especially by species of conservation concern, are not suitable for windfarm development (e.g. in Spain, regional recovery plans prohibit windfarms in areas important for breeding and feeding imperial eagles *Aquila heliaca*). Site selection is crucial to minimising collision mortality. The precautionary principle is advocated where there are concentrations of species of conservation importance. It is therefore very important that alternative locations are proposed for the potentially most hazardous windfarms.

Wind speed and direction, air temperature and humidity, flight type, distance and height, time of dayand topography all influence the risk of collision, as do species, age, behaviour and stage of the bird's annual cycle. All these factors need to be incorporated in collision risk assessments. Collision risk is greatest in poor flying conditions, such as strong winds that affect the birds' ability to control flight manoeuvres, or in rain, fog, and on dark nights when visibility is reduced. In these conditions, the flight height of migrating birds tends to be greatly reduced. Lighting of turbines has the potential to attract birds, especially in bad weather, thereby potentially increasing the risk of collision.

Few studies attempt observations in poor weather and visual observations are limited in such conditions. However, remote techniques can be used to extend observations beyond the visible spectrum, e.g. radar, thermal imagery and, at the very least predictions of the likely frequency of the weather conditions that increase collision risk can be used to inform the risk assessment.

Most studies have been of small turbines, often in small clusters; the implications of newer, larger turbines and larger windfarms may be different. The importance of windfarm location and layout in determining the risk of collision by birds with wind turbines is apparent from studies both onshore and offshore.

Collision mortality arises as a result of collision with turbines, meteorological masts and powerlines. Thus, assessment of bird collision risk and mortality, arising from collision or electrocution, needs to include wind turbines and associated structures, including overhead powerlines transporting energy from the windfarm. It is recognised that the actual rate of collision is likely to be under-recorded, owing to the limitations of the study techniques, particularly corpse searches, so it is essential that calibration is undertaken at each site to enable correction factors to be applied to produce more realistic estimates of collision mortality.

Collision risk models provide a potentially useful means of predicting the scale of collision attributable to wind turbines in a given location, but only if they incorporate actual avoidance rates in response to fixed structures and post-construction assessment of collision risk at windfarms that do proceed, to verify the models. Population models provide a means of predicting whether or not there are likely to be population level impacts arising from collision mortality. Again, they require post-construction verification at consented windfarms to test the validity of the predictions and the models.

– Behavioural observations – collision risk and avoidance

Behavioural observations of birds in windfarm areas before construction provide the basis of an assessment of collision risk. Fixed point observations of flight behaviour, flight lines into, through, and out of the area and information about birds' use of the area all help to inform the environmental assessment and provide input data for collision risk models (Band *et al.* 2002, see also Annex 1). If a windfarm is constructed, similar observations are essential to enable an assessment of flight response to turbines (avoidance, collision) to enable predictions to be tested. Visual observations provide the majority of observations, but increasingly the value of radar (with supplementary species identification) and thermal imaging equipment is recognised to provide information beyond the reach of the human eye, notably during night and poorer weather conditions.

The experimental windfarm, at Oosterbierum in The Netherlands, was the subject of studies between 1984 and 1991. The study area comprised 18300 kW, wind turbines, together with meteorological towers and control buildings. Winkelman (1992b) observed large-scale autumn migration, notably into headwinds, to be at the height of the turbine blades. Studies of birds' responses at night to turbines, using thermal and passive imaging equipment plus radar, revealed that most flight reactions occurred with headwinds (87%) and least with tailwinds (29%) (Winkelman 1992b). Mortality or injury was caused by either collision with the rotor blades or by the force of the wake, behind the rotor, driving birds down to the ground.

Observations at Oosterbierum in daylight within 200-300 m of turbines indicated that over 75% of all reactions took place within 100 m, ducks reacting at the greatest distance and small passerines reacting closest to the wind turbines. Habituation was indicated for local birds that displayed an earlier and more graduated flight response to turbines. In daylight, proportionately fewer migrants reacted to non-operational than to operational turbines and displayed most response at the height of the rotor and at 0-50 m above the top. The response increased with fading light and with multiple turbines, particularly when closely spaced, rather than individual ones. However, when turbines were at a standstill, there was no difference in response with flight height for migrants or local birds (Winkelman 1992c). Flights were observed to be mostly at the height of the turbines (up to 50 m) during dispersal at sunrise from nocturnal roosts to feeding areas, the end of nocturnal and start of diurnal migrations, and to some extent at sunset as flights to roost and nocturnal migration started (Winkelman 1992b, 1995). Groups of ducks and gulls flying to roost were observed making several attempts before flying through the windfarm (Winkelman 1992c), which could increase the risk of collision.

During 1994-98, nocturnal studies of flight paths and altitudes were undertaken, during spring, autumn and winter, at several locations near tidal areas of the Delta and Wadden Sea in The Netherlands (van der Winden *et al.* 1997 & 1999). The studies combined the use of vertical and horizontal marine surveillance radar plus observations and recordings of calls. The study recorded substantial movements between mudflats and high tide roosts, several 1000 movements per hour. The average altitude was <100 m, mostly <75 m, so potentially within the height zone occupied by rotating turbine blades, with Eurasian oystercatcher recorded at the lowest and grey plover *Pluvialis squatarola* and Eurasian curlew at the highest altitudes recorded, whilst dunlin *Calidris alpina* and bar-tailed godwit *Limosa lapponica* were recorded at intermediate altitudes. Flight was generally higher with tailwinds than with headwinds. The authors emphasise the fact that, as waders do not necessarily use the same roosts at night as used in daylight, it is necessary for site assessments for windfarms to take into account the local situation, day and night, before planning the location of turbines.

Similar studies were undertaken at Ijmuiden to record the behaviour of spring migrants (Dirksen *et al.* 1996). Spring migration flights along The Netherlands coast occurred during daytime, evening and at night, mostly at low altitudes and at short distances from the coast, within 700 m of the shoreline, although radar echoes were recorded from up to 2 km. Most waders were recorded at heights of 20-50 m, whilst most gulls were recorded below 20 m altitude.

Radar studies of nocturnal movements of diving ducks between feeding and roosting areas on the Ijsselmeer, in the Netherlands indicated that most flew below 75 m, flight height being lower in inclement conditions such as strong headwinds (Dirksen *et al.* 1998a & b, Spaans *et al.* 1998a & b, van der Winden *et al.* 2000). Tufted duck and common pochard movements took place predominantly during darkness, whereas those of greater scaup occurred mainly at dusk and dawn at an altitude equivalent to the height of the rotor blades, so putting these species at risk of collision. During moonlit nights, tufted duck and common pochard flew between the four turbines, whereas on moonless nights more birds flew parallel to the line of turbines i.e. around the outside of the windfarm, rather than between the turbines. This indicates that local wintering birds may habituate to the presence of wind turbines and so avoid collision (Spaans *et al.* 1998a & b). However, this study provides an indication of the barrier effect that turbines may have to avian flight paths, especially in conditions of poor visibility. The implications of this may be different for large windfarms such as those being proposed for various north European locations, which will make design and layout considerations all the more important. The Ijsselmeer is the subject of windfarm proposals and there is concern that bird collision risk, especially during darkness, could be high if turbines intercept flight paths between feeding and roosting areas.

Observed flight reactions to wind turbines in Schleswig-Holstein indicated that waders, terns and wildfowl reacted 200-500 m from the turbines, whereas gulls reacted at 100-150 m distance (Koop 1997). Gulls and waders showed an increase in flight height or changed direction to fly over or around, whilst wildfowl manoeuvred sideways to fly round the turbines. The turbines were observed to disrupt flock formation in barnacle geese *Branta leucopsis*. Observations such as these are most useful when combined with similar observations from other windfarms, using standard methods and combined with supplementary information on weather conditions, wind speed and direction, and the birds, e.g. purpose of flight.

Studies of the behavioural response by common terns *Sterna hirundo* to powerlines, at different stages during the breeding cycle, indicate that their susceptibility to collisions increases when adults are making frequent foraging flights to provision chicks and when newly fledged young are about (Henderson *et al.* 1996). Avoidance responses to powerlines, which intercepted the flight path between breeding and feeding areas, increased in frequency with increasing wind speed, notably into head winds. This work illustrates the potential for differences resulting from weather, breeding stage and age of bird, which need to be taken into account when assessing collision risk and mortality.

Observations of daytime flight behaviour by gulls, mainly herring and lesser black-backed *Larus fuscus*, and common terns, at the East dam in the port of Zeebrugge, in Belgium and at Maasvlakte in the port of Rotterdam, in The Netherlands, found that wind turbines did not present a barrier to the birds, which flew between the turbines to and from their breeding colonies and marine feeding areas (Everaert *et al.* 2002, van den Bergh *et al.* 2002). As observed by Henderson *et al.* (1996), breeding adults tend to fly much closer to structures in their flight path when making frequent flights to provision chicks than at other times, and they may sustain collisions as a consequence (Everaert *et al.* 2002).

At Blyth, in the UK (Still *et al.* 1996), fixed-point observations were made of the flight activity of the internationally important population of purple sandpipers and the further five most numerous species (common eider, great cormorant, black-headed gull, great black-backed gull *Larus marinus* and herring gull). Observations suggested that gulls flew between the turbines, especially in good weather. Both herring and great black-backed gulls suffered mortalities (a minimum of seven herring gulls and seven great black-backed gulls were recorded killed through collisions in the 2.5 year operational period studied). Black-headed gulls appeared to be less vulnerable, due to their lower flight height, below the sweep of the rotors (<15 m). Although data are limited by the rarity of observed incidents, the occurrence of common eider and gull collisions did appear to coincide with poor weather and poor visibility. Common eiders at the rear of flight formations were observed to fly critically close to the rotors. During the limited autumn passage over the area, flocks of ≤100 common blackbirds *Turdus merula***,** redwings *Turdus iliacus* and fieldfares *Turdus pilaris* were observed. Larger flocks flew above the turbines, whilst small flocks of 15-30 birds passed between them. No collisions were observed, nor was there any indication of sudden avoidance behaviour during the observation period.

There are particular concerns about the implications of windfarms for migrating birds and indications that they might be vulnerable to collisions, especially when migrating at night and in conditions of poor visibility (Winkelman 1992b, 1995). Useful information on migration may be found in Alerstam (1990) and Richardson (2000), in particular. In summary:

- Most land birds fly at night, especially in the early part from soon after sunset and so are gaining altitude in twilight.

- Most nocturnal migration by passerines is at high altitude in good weather (1000-1500 m) (Alerstam 1990), well above turbine height.
- Most birds of prey migrate during the day.
- Most water birds migrate during day and night; many shorebirds depart in late afternoon/early evening (e.g. Gudmundsson 1993, Tulp *et al.* 1994).
- Migrants prefer tail winds or light headwinds (also Bruderer 1980).
- The risk for migrants is principally during take-off and descent or due to bad weather (rain, mist) or strong headwinds forcing them to fly at lower altitude.
- Migration stopovers may bring more migrants into wind turbine height zones during ascent and landfall, especially species that lose or gain height gradually e.g. swans.
- It has been demonstrated that diurnal migrants are often concentrated along linear features such as coastlines or valleys, but do cross mountain ranges sometimes, especially at cols. Flight height is also reduced over ridges.
- As study methods for nocturnal migration are refined, more examples of similar behaviour at night, to that observed by day, are apparent.
- Most long-distance migration sea-crossings are on a broad front, although there are narrow sea passages at which migrants concentrate, notable examples being Straits of Gibraltar, the Bosphorus and Falsterbo.

Migration flight altitude is dependent on many factors, such as flight distance, weather, wind speed and direction, air temperature and humidity, time of day and topography, as well as the species, size and structure of the bird (Alerstam 1990). For example, in fog birds may be grounded or fly at lower altitude, and may become disorientated, especially in the vicinity of lit structures (see section 2.67). Waders leaving Mauritania on their northward migration in spring were observed, with an optical range finder, to be still climbing above 1.5 km when they disappeared from view (Ens *et al.* 1990). The maximum recorded flight height is of whooper swans using strong winds to assist passage at 8.2 km (Elkins 1983).

There is a lack of information about migratory routes, especially nocturnal ones and about any concentrations at critical heights which would increase the risk of collision. Erni *et al.* (2002) found that local weather, in particular wind and rain, explained most of the variation in nocturnal migration densities, and that duration of rainfall was more important than intensity alone. Winkelman's studies (1992b, 1995) of windfarms in The Netherlands suggested that most diurnal migration and local movements were below 10 m, whilst nocturnal migrations, especially in autumn were up to 50 m or more, i.e. at the height of the turbine blades, in the vicinity of coastal windfarms. Deng & Frederick (2001), studying transmission powerlines in the Florida Everglades, also observed nocturnal flights to be at higher altitude than diurnal flights so, although birds were observed to be less likely to react to powerlines at night, there was a lower potential for them to come into the collision risk zone.

Pre-construction studies of migrants in the Norris Hill Wind Resource Area, in southern Montana, USA, found that visual observations of migrants under-estimated passage rates, so marine surveillance radar was used to record passage during daylight and darkness (Harmata *et al.* 2000a & b). Daytime visual observations were used to verify species identification, although there may have been some different species at night not accounted for. Autumn migration was more protracted than vernal migration, a feature recognised in other migration studies. The highest passage rates were recorded within four hours of sunset. Average altitude was higher in spring than in autumn, largely attributed to the departures in spring and arrivals in autumn at the nearby staging site of Ennis Lake. Passage rate decreased with declining trend in barometric pressure in autumn (headwinds), whereas it increased in spring (tailwinds) (see also Dierschke & Daniels 2003, cited in ICES 2003[1]). Migrants avoided flying over higher topographic features, especially during strong headwinds, and waterfowl in particular were observed to adopt low altitude flight along valleys at such times. Such studies assist with determining the collision risk associated with proposed windfarm developments, as indicated above.

Moorehead & Epstein (1985) (cited in California Energy Commission 1995) identified large wetland birds, such as geese and cranes *Gruidae*, and low-flying migratory songbirds as being especially susceptible to collisions with windfarm installations. They emphasised that collision potential varies with weather, terrain, turbine placement, rotor design and rotor speed, and identified the provision of visual cues and site selection outside critical areas among their recommended mitigation measures.

A single experimental wind turbine situated on a ridge top within a major migration corridor in Yukon has been the subject of a 5-year monitoring programme (Mossop 1997). The main species involved were large, migrant waterfowl, notably tundra *Cygnus columbianus* and trumpeter swans *C. buccinator*, ducks and birds of prey, together with local breeding populations of passerines and willow ptarmigan *Lagopus lagopus*. No flocks of waterfowl were observed within 200m of the turbine and in any case all movements were at a substantially lower altitude, along the valley. Raptors, mainly golden eagles, commonly moved through the site; no collisions were recorded with the wind turbine. The few collision fatalities (6 in winter, all ptarmigan species) recorded by the study were associated with a control tower of lattice construction with guy wires.

At the Klickitat County proposed windfarm development in Washington State, USA, pre-construction Before-After Control Impact (BACI) studies were initiated (Erickson *et al.* 2000). Of the nearly 10000 birds of 73 species observed during the first year, only 13% of flights were recorded within the likely rotor swept area, but over 40% of raptor movements were within the height category that would maximise their collision risk, highlighting species group differences in collision risk.

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[1] This draft report is subject to review by the relevant ICES Science Committees during the Annual Science Conference and Statutory Meeting, September 2003, and is cited here on that understanding.

Winkelman (1992c) considered that 'windfarm layout' was probably important in reducing collision risk. For wintering and feeding, and possibly breeding birds, a (dense) cluster of turbines was thought to be potentially less damaging, to dissuade them from flying amongst the turbines (see also Larsen & Madsen 2000). But, for migrants, a line formation in parallel to the main flight direction or a loose cluster was thought to be the best arrangement.

Tarifa is a major migration corridor and also has the greatest potential for wind energy generation in Spain (Janss 2000), bringing direct conflict. The early windfarms were installed without any collection of data beforehand, and large numbers of birds collided fatally with turbines, notably common kestrels *Falco tinnunculus* and griffon vultures (SEO[1]/BirdLife 1995).

Studies in the Strait of Gibraltar, Andalusia, in Spain, concentrated on breeding and migratory soaring birds at two windfarms, which together comprise 256 turbines (SEO/BirdLife 1995). Flight behaviour within 250 m of turbines was studied to enable a collision risk assessment. At Pesur, soaring flights at low wind speeds (≤8 m/s^{-1}) and crossing flights that commenced below blade height increased the risk of collision, as vultures showed little reaction to the turbines with only 2% altering their approach flight pattern. Furthermore, collisions occurred in conditions of good visibility, indicating little manoeuvrability by the vultures. A single group of 28 wind turbines was responsible for 57 % of griffon vulture mortality. SEO/BirdLife advocated operation of these turbines only at wind speeds in excess of 8.5 m/s^{-1}, but this corrective measure was not implemented by the companies.

Consequently, a series of post-construction surveys has been implemented, including that by Janss (2000) of an installation of 66 turbines on top of a mountain ridge. The study covered the windfarm area and two reference areas and assessed the species, numbers and productivity of breeding birds, the numbers of winter roosting birds, counts and flight information (height, direction and type – flapping, gliding or soaring) for local and migrating birds, flight behaviour and collisions in the windfarm area. The main findings were as follows:

- Migrants passed over the windfarm at higher average altitude (>100 m) than over the reference areas (*ca*. 60 m).
- Flight altitude of migrants was positively correlated with ambient temperature and negatively correlated with wind speed, so the collision risk for migrants varies with weather conditions (long-distance migrants seek to maximise flight efficiency and minimise energy expenditure).
- Local birds showed no difference in flight altitude above the windfarm or reference sites and no relationship between flight altitude and wind speed.
- Birds changed flight direction more often when crossing the windfarm than elsewhere.

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[1] Sociedad Espanola de Ornitologia, Madrid, Spanish BirdLife International.

The extent to which the differences between the windfarm and the reference areas are attributable to the windfarm remains uncertain owing to the absence of pre-construction data, but indicates flight avoidance of turbines by many birds.

Spanish experience indicates a detrimental impact of windfarms on feeding raptors (e.g. juvenile dispersion areas) and steppe birds. The National Strategy for the Conservation of the Spanish Imperial Eagle in Spain (Ministry of Environment, unpublished) advocates that windfarms should not be located in critical areas for the species. The advanced drafts of the Regional Recovery Plans for the Spanish Imperial Eagle in Castilla y León and Castilla-La Mancha regions, prohibit this industry in the critical breeding and feeding areas for the species (including juvenile dispersion zones).

– *Corpse searches*

Actual observations of collisions are relatively rare and so often not recorded during studies. Corpse searching has been the main means of assessing collisions, but has serious limitations, leading to under-recording of collisions. Few studies involving corpse searches have looked systematically for passerines, in any case birds that have collided with the rotating blades are likely to be extremely difficult to find and so corpse searches may be of limited value for small birds.

Remote techniques have considerable application for measuring such events, especially offshore. Research is underway to develop automated recording systems, based on heat sensors to trigger recording and transfer of information to specially developed computer software, e.g. infra-red video cameras to record both flight behaviour in close proximity to turbines and actual collisions (Kahlert *et al.* 2000, Desholm 2003). There is also the potential for development of pressure or vibration sensors on turbine blades. However, any study method has its limitations and it is important that these are understood, corrected for as far as possible, and taken into account in interpretation of the results.

At Urk (Winkelman 1989) and Oosterbierum (Winkelman 1992a), both in The Netherlands, most collision fatalities were found after nights with poor flight and visibility conditions. Mean corrected 'daily' collision rates per turbine were <0.1 in autumn and spring. The number of corpses in autumn was 2-3 times that recorded in winter or spring (Winkelman 1989). Collision rate was higher in fully operational windfarms (i.e. an increased number of operational turbines), than during construction and partial operation (Winkelman 1989, 1992a, b, c, 1995, also summarised in Spaans *et al.* 1998a).

Winkelman (1992b) recognised that estimates of collision mortalities were likely to be underestimated, as a result of at least some non-fatal injuries leading to subsequent mortality away from the site. Another source of potential underestimation arises from the inability to establish the cause of death in all cases, including those due to wind turbines (Winkelman 1992a). Winkelman (1989, 1992a, 1995) also recognised that collision rate estimation depended on scavenging rates by predators and other animals, search frequency, search area and search efficiency, and investigated the latter particularly in several studies. Search efficiency for passerines up to the size of a common starling averaged 45% (30-55%, n=56) at Oosterbierum (Winkelman 1992a) and 73% (60-83%, n=22) at Urk (Winkelman 1989), and varied with vegetation height. Search efficiency tended to be higher for larger birds. Winkelman estimated that 2.5% of all birds in autumn passing at rotor height, during operation of the turbines, would be killed, taking into account the underestimation of mortality from corpse searches (Winkelman 1992b).

Morrison (2002) also identified causes of variation in corpse searches due to observer training, vegetation type and season, and size of bird. Consequently, he emphasised the need for correction factors to be calculated based on season and vegetation specific data for every study, and not just drawing on values in the literature because of the substantial variability between studies. Similarly, he advocated scavenging trials to be carried out for a period of sufficient duration to detect when and if an asymptote is reached, to determine the appropriate interval for corpse searches and to provide calibration.

Several studies indicate rapid removal by scavengers within a few hours. For example Windcluster Ltd. (1993, cited in SGS 1996/1) showed that 50% of the small carrion was removed within 6-12 hours of being put out as part of the experiment to assess the effect of scavenger removal at Haverigg Windfarm in Cumbria, UK. Similarly, in an experiment to investigate scavenging rates under overhead powerlines, 70% of the dead starlings placed in the evening had disappeared by the next morning (von Heijnis 1980). He also found that injured birds dragged themselves up to 2 km from the collision site. Increased collisions were attributed to panic reaction when disturbed, changing visibility of the wires, and unfavourable weather conditions such as rain and strong winds. Whilst, arguably, powerlines and in particular the earth wire, are likely to be less visible than a wind turbine, nonetheless information from studies of collisions with powerlines can yield useful information with respect to wind turbines and associated structures, including power transmission lines.

At Dun Law windfarm, in Scotland, a systematic corpse search and calibration technique has been instigated to coincide with the peak presence of pink-footed geese at Fala Flow (Gill 2001). The calibration experiment involved placement of goose corpses for re-location by another observer and for assessment of scavenging rates. Visits were made at approximately weekly intervals. The most striking result of the experiment was the high (35%) removal (22%) or movement (13%) of the placed corpses, presumed to be by foxes, which emphasises the need for such calibration to be applied to any collision victims found. Search efficiency was estimated to be at least 83%, allowing for the prompt removal by scavengers of some of the placed corpses, but the carcases were placed within 5 m of the transects which may not reflect the situation for actual collision cases and may inflate search efficiency. No goose collisions have been recorded to date, although a dead curlew found on site near an electricity pylon may or may not have been the result of collision (Gill 2000b).

The Before-After Control-Impact (BACI) studies implemented at Ponnequin, Colorado, USA, identified rapid scavenging rates for passerines (1-3 days) but large carcases remained for at least 1-2 months (Kerlinger *et al.* 2000). Search efficiency was variable, only 25% of passerines were found, but 75% of medium-sized carcases such as ducks, and all large carcasses, e.g. large raptors, were found. Studies at Buffalo Ridge Wind Resource Area, in Minnesota, USA, recorded an observer efficiency of 78.8% in conservation grasslands and cropped land, with scavengers removing 39.5% of carcasses over 7 days (Osborn *et al.* 2000). These and other studies (e.g. Thelander & Rugge 2000) highlight the potential for underestimating collision rates, for passerines in particular, and the consequent need to correct measures of collision rates for the confounding variables (such as search efficiency for corpses, predator removal of corpses etc), by means of experimental work.

An assessment of the species composition of collision fatalities associated with windfarms, whilst recognising the likely bias towards recording large birds, showed that, of 841 reported in California, 41.5% were diurnal raptors, 20.1% were passerines (excluding USA non-protected house sparrow *Passer domesticus* and starling) and 11.1% owls (Erickson *et al.* 2001). Away from California, passerines were the most common collision victims, comprising 78% of the 192 documented fatalities. Erickson *et al.* (2001) interpret the results as indicating that, whilst turbines are generally below the flight altitude of most nocturnal migrants, weather and other factors that reduce flight height may lead to collisions with wind turbines, and other structures. Annual collision fatality estimates, associated with windfarms, are calculated for the USA and put into context with other sources of collision mortality. At the present level of development of wind energy in the USA, wind energy appears to be responsible for a substantially lower proportion of mortality than other causes of collision. However, it is not clear whether wind energy-related mortality is additional to other causes of mortality and whether there are population level effects now (although see Hunt 2002), or potentially in the future, arising from the cumulative effects of multiple wind installations.

Erickson *et al.* (2001) conclude that the most significant factor related to bird mortality at windfarms studied to date is the siting of wind plants. They also stress that vulnerability to collision is species and site specific, with a variety of different groups (e.g. raptors *Accipitridae*, owls *Strigiformes*, passerines) prone to collision with turbines in different situations (see also Thelander & Rugge 2000).

A four-year study of three wind plants, comprising over 350 turbines, on Buffalo Ridge estimated 2.8 bird collisions per turbine (up to 4.45 at one of the installations), per year (Johnson *et al.* 2000). Most of the recorded fatalities were nocturnal migrant passerines (76.4%), in spite of the acknowledged problems of detection of small birds and high, rapid scavenging rates, which indicate the likelihood of higher actual mortality rates. Radar studies have indicated annual migration of *ca* 3.5 million birds through this wind resource area.

In the Altamont Wind Resource area, California, USA, there are over 7000 turbines (BioSystems Analysis Inc. 1990, Orloff & Flannery 1992). Carcasses searches found

182 carcasses in sample sites around the Altamont Pass Wind Resource Area between 1989 and 1991, of which 119 were raptors (Orloff & Flannery 1992). Of these, 55% of deaths were attributed to collisions with turbines, 8% to electrocution, 11% to collisions with wires and 26% to unknown causes. Proportionally more American kestrels *Falco sparverius,* red-tailed hawks *Buteo jamaicensis* and golden eagles were killed than their abundance in the study area would predict by chance, and the authors indicated that their hunting behaviour might be contributory to their higher collision mortality. The estimated collision fatalities for the whole Altamont Pass Wind Resource Area was at least 39 golden eagles alone per year, from an estimated annual raptor mortality of 164 to 403 birds.

Estep (1989) collated earlier records of avian mortality resulting from collision or electrocution with wind energy-related structures in Altamont Pass and Tehachapi Pass in California. This similarly found raptors to be primarily affected, indicating an ongoing problem with these windfarm, i.e. no sign of habituation, probably because of the reportedly high prey abundance making the area very attractive to foraging raptors. Howell & Di Donato (1991) identified significant topographical features associated with collision mortality in California. Notably mountain passes and hill shoulders, which tend to be the preferred crossing places for soaring species, were associated with multiple collisions. These authors expressed concern that windfarm-related collision mortality of golden eagles could have a significant population effect, at least at a local level. It is now acknowledged that these facilities were constructed in areas without an understanding of their use by birds and where the large numbers of birds present, of species susceptible to collision, produce a high risk of turbine collisions (Erickson *et al.* 2001).

Mortality at Tarifa, Spain, has been very high compared with the results of other studies in Europe and the USA (SEO/BirdLife 1995), even in fine conditions, highlighting the need to avoid internationally protected sites or other IBAs and other locations with vulnerable species or migratory concentrations. Studies in Andalusia, Spain (SEO/BirdLife 1995), combined searches for corpses and injured birds, at least weekly around a random sample of 87 (34%) of the 256 turbines and beneath powerlines, during the year 15 December 1993 to 15 December 1994. The 51 fresh raptor carcasses found included 30 griffon vultures, 12 common kestrels, 3 lesser kestrels *Falco naumannii*, 2 short-toed eagles *Circaetus gallicus*, 2 eagle owls *Bubo bubo*, 1 black kite *Milvus migrans* and 1 unidentified raptor, but no correction factor was applied to allow for scavenger removal, search efficiency etc. for these species, with the exception of common kestrel. Several experiments were implemented to assess predation losses of common kestrels. Including corrections for predation removal, there were estimated to be 49 common kestrel collision casualties. For the remaining species, collision mortality figures are consequently minima. There were no formal searches for small birds, but 17 were found incidentally, for which it was not possible to apply an extrapolation factor.

There were differences between the two study sites (estimated collision rates per turbine per year of 0.15 at Pesur and 0.03 at site E3) and differences between rows of turbines within the sites; 57% of vultures killed were attributed to 28 of the 190 turbines at Pesur (SEO/BirdLife 1995). Whilst recorded collision rates per turbine were low, the total number of birds involved, their protected status and the potential cumulative collision victims at other windfarms in the area, and in additional years, led to concerns of significant adverse impacts on populations of birds of conservation concern, notably the large soaring species. An important conclusion of this study is that not all the wind turbines caused the same impact, so the assessment of alternative locations and layout is the most important element to minimize the impact of a windfarm on birds.

Another cluster of windfarms, poorly sited in an important area for migrating birds in particular, has led to substantial collision mortality at Navarra, in Spain (Lekuona 2001). Studies of bird use, collision risk and collision mortality in the area of 400 turbines (but not including the powerlines and other associated infrastructure), found that raptors and migratory passerines were particularly affected. The author reported rapid and high scavenging rates of corpses, 62% of carcasses found disappeared within 24 hrs, and hence the likelihood of underestimation of collision mortality on the basis of found corpses – 138 birds found dead during weekly searches between March 2000 and March 2001. He also observed the now familiar influence of weather in influencing collision mortality. The high collision mortality of raptors comprised mostly griffon vultures (88 corpses found), most at one of the windfarms, Salajones. Other species among the collision victims were golden eagle, eagle owl, booted eagle *Hieraaetus pennatus*, sparrowhawk *Accipiter nisus* and common kestrel. After applying correction factors for scavenger removal, search efficiency etc after Winkelman (1992a), he estimated at least 8 vultures per turbine per annum (22 birds of all species/turbine/year) at Salajones. Mortality of migrating passerines was especially noted during autumn passage at El Perdon, estimated to be 64 collisions per turbine per year after applying the Winkelman method for correction.

At Blyth, in the UK (Still *et al.* 1996) carcasses searches were augmented by several experiments, including one to measure the recovery of released corpses, to assess pre-construction mortality rates and causes, including those associated with nearby powerlines. Over the 2.5-year operational period, 31 victims of windfarm collisions (of four species) were recorded, equivalent to 1.34 bird strikes per turbine per year. Great cormorants appeared to have a low collision risk, even in poor weather conditions. However, the collision rate for wintering common eiders was higher than expected following construction of the windfarm. Common eiders are likely to be prone to collisions because of their high body mass to wing surface ratio (three collided with existing structures in the harbour and at least 12 with the wind turbines). The predicted impact on the local breeding population represented an estimated 0.5-1.5% additional mortality. The mortality of common eider, herring and great black-backed gulls, associated with the wind turbines, was considerably higher than the background mortality (pre-construction mortality, in the absence of a windfarm). Of the 66 dead birds found, over the entire study period, for which the cause of death could be determined (unfortunately only a small proportion of the total carcasses), 12% were collision victims, 20% due to starvation, 15% from fishing line entanglement, 14% from oil contamination and 26% from predation (although the last category may have included other actual causes of death – *ed.*). The reduction in subsequent collision mortality indicates that habituation to the presence of wind turbines may have occurred (Painter *et al.* 1999). Another experiment measured the recovery of released wooden floats (simulation of shoreward drift of corpses without scavenger removal). This experiment confirmed expectations that few corpses were likely to be washed ashore, illustrating the limitations of corpse searches for assessing collision mortality and the likelihood of consequent underestimates, especially in coastal areas.

At the East dam in the port of Zeebrugge, in Belgium, 55 collision fatalities were found under the 23 operational wind turbines in the course of a year (Everaert *et al.* 2002). After correction for search area, search efficiency and predation, it was estimated that at least 531 birds collided with the wind turbines. The estimated collision rate ranged from 0 to 125 birds per wind turbine per year. The mean number for the whole wind park was 23 birds/wind turbine/year and 39 birds/wind turbine/year for the 12 seaward turbines. The authors acknowledge the likely under-recording of collision mortality, especially of small birds. Herring gull, lesser black-backed and black-headed gulls were recorded as the main casualties (80% of found corpses, 45% estimated mortality); these were also the most numerous species present. However, rarer species such as common tern, little tern *Sterna albifrons*, kittiwake *Rissa tridactyla*, peregrine *Falco peregrinus* and stonechat *Saxicola torquata* were also among the casualties (Everaert *et al.* 2002). For terns, the estimated collision rate was 28 in one year. Based on the number of gulls passing the turbines during day and night, 1 in 3,700 collided (1 in 2100 at the height of the rotating blades) and for Common terns during the day, 1 in 3000 collided (1 in 600 at the height of the rotating blades). The number of collisions seemed to be highly dependent on the number of passing birds, rather than the size of the wind turbine.

At Kreekrak, in the Netherlands, studies of collision mortality associated with a coastal windfarm, comprising 5 turbines, were instigated preparatory to possible expansion of the windfarm (Musters *et al.* 1995, 1996). Corpse searches on alternate days took place over one year and cause of death was established where possible. Monthly recovery of experimentally placed corpses was undertaken. Unsurprisingly, recovery from water was more difficult so estimates of mortality were based on the land-only figures. There was no significant difference in the rate of land-based recovery during the year. Predictions of mortality were made for a 20-turbine windfarm and indicated an average of 0.01 (0.006-0.02) victims per turbine per day. It is not clear whether any allowance was made for injured birds that died away from the search area, or how representative land only figures might be of the total mortality. This study too highlights the problem associated with assessing collision mortality offshore, where remote technologies are likely to be most valuable.

Recent research has indicated that high contrast patterns on turbine blades could reduce collision risk by increasing the visibility of the rotating blades (McIsaac 2001), but it is not known to what extent this might avert collisions, especially in conditions of poor visibility. Furthermore, such measures may be unacceptable on landscape grounds.

The results of studies, such as those referred to above, have contributed to decisions on windfarm development proposals. In the UK, case law has taken the precautionary approach in decisions relating to migratory geese. At Largie, Scotland, the Secretary of State for Scotland concluded that no suitable planning conditions could be attached to any planning consent and that too many uncertainties remained regarding the level of avoidance of turbines by flying Greenland white-fronted geese *Anser albifrons flavirostris* (Russell 1996). On Islay, Scotland, again uncertainty over the potential collision risk led to refusal of planning permission for a windfarm on land adjoining the SPA (June 1999). Population Viability Analysis indicated that there was between a 5% to 20% chance of mortality from the windfarm causing a decline in the over-wintering population of the Greenland white-fronted geese (McCulloch 1998).

The weight of evidence to date indicates that locations with high bird use, especially protected species, are not suitable for windfarm development (NWCC 2002).

– *Implications of collision mortality – predictive population models*

In the absence of pre-construction data and with no reference area, but with alarming numbers of raptors killed as a result of collision with turbines in the Altamont Pass Wind Resource Area, researchers have turned to modelling population dynamics (Hunt *et al.* 1999, 2002, Thelander & Rugge 2000). The aim of this work is to investigate the annual rate of population change in golden eagles, the principal raptor of concern, in order to test whether the population is stable, increasing or decreasing and, ultimately, to determine whether the windfarms significantly increase mortality.

The study comprises a post-breeding survey, mark-resightings of golden eagles using radio-telemetry and nest monitoring. The model incorporates three age categories, namely fledglings, non-territorial sub-adults and floaters, and territorial birds, with the emphasis being on females, for which annual reproduction is assessed (Shenk *et al.* 1996). Survival and transition between age-categories are also included in the density-dependent model. This work requires a long timescale to fully verify the model predictions, in view of the lifespan of golden eagles and year-to-year variability. The population modelling by Hunt *et al.* (1999; Hunt 2001) indicated that the golden eagle population was declining in the Altamont region, at least in part due to windplant mortality.

Mortality attributable to energy generation or transmission was observed mainly in non-breeding sub-adults and floaters (Hunt *et al.* 2002). This was thought to arise when the birds were actively hunting in the windfarm area. The lower recorded mortality of juvenile eagles was attributed to their lesser tendency to hunt live prey. Most home ranges of breeding birds were outside the wind resource area, which is thought to be the reason why few deaths of radio-tagged breeding adults were recorded in association with wind turbines or powerlines (Hunt *et al.* 2002). This study has not so far recorded a decline in territory occupancy (Hunt *et al.* 2002).

However, the high annual losses among sub-adults and floaters could lead to a shortfall of birds of breeding age to occupy territories that become vacant. The authors acknowledge that it is not known whether the floaters that enter the breeding population are local or immigrants, and hence whether or not the local population is maintaining a supply of non-breeding adults to buffer the breeding population.

Sensitivity analysis was used to determine the effects on population growth rates of survival of different age classes for a range of species (Morrison *et al.* 1998). Notably for eagles, changes in adult survival have the largest impact on population growth. This analytical approach was seen as a valuable component of assessments of the influence of windfarms on populations.

Whilst the use of validated population models is feasible for large raptors, it is costly and a long-term process not necessarily appropriate for some other species nor to all windfarm proposals. However, in the case of Altamont, the scale of raptor mortality warranted radical measures as one of the most notable wind energy locations (others include Tarifa and Navarra in Spain) to highlight the potential damage that poorly-sited windfarms can cause.

There are also documented methods for investigating the relationship between the number of birds displaced and the decline in population size, which can be usefully applied to windfarms (Goss-Custard *et al.* 1995, Sutherland 1996, 1998, Goss-Custard *et al.* 2002). In the UK, work is in progress to develop predictive models to determine the potential impacts of offshore windfarms on common scoter (COWRIE, unpubl.) (http://www.crownestate.co.uk/estates/marine/windfarm/cowrie .shtml).

2.2.2 Collision risk and mortality offshore

– Summary

This section considers collision risk from offshore windfarms, although there is very limited information to date.

The importance of windfarm location in determining the risk of collision by birds with wind turbines is just as apparent from offshore studies, as for onshore ones.

In good weather conditions, during daylight, common eiders were observed to avoid flying and landing within 100 m of the Tunø Knob wind park in Denmark (Guillemette *et al.* 1998). Tulp *et al.* (1999) investigated nocturnal flight activity and found that both common eiders and common scoter were active at night, but flight intensity was reduced on dark nights, compared with moonlit conditions. Nocturnal flight activity, especially on moonlit nights, was reduced in the vicinity of the windfarm, with a diminishing effect observed up to 1000-1500m away from the nearest turbine. Within 500 m from the windfarm, relatively more groups of common eiders flew around rather than between the turbines. Birds approaching the windfarm parallel to the alignment of turbines were more likely to cross the park than if the approach was perpendicular to the alignment. Thus, windfarms can act as barriers to bird movement, although whether this is a problem will depend on the size of windfarm, spacing of turbines, the extent of displacement of flying birds and their ability to compensate for increased energy expenditure. The authors recommended:

- that turbines are sited close together to minimise the area accommodated by a windfarm (there are spacing constraints arising from the size of the wind turbine, *ed.*);
- that turbines should be grouped so as to avoid alignment perpendicular to main flight paths (see also Winkelman 1992c);
- the provision of corridors – potentially a few kilometres wide – between groups of turbines to allow passage by birds;
- deep placement of turbines to avoid shellfish beds.

Krüger & Garthe (2001) found migratory flights into headwinds to be lower and slower, thereby conserving energy, whereas in tailwinds flight is more efficient at higher altitude. In particular, higher proportions of red-throated divers, common eiders and common scoters fly lower over water as wind speed increases, especially in headwinds. However, in tailwinds an increasing proportion of birds fly at higher altitudes ≤25 m. Most diurnal movement was recorded at low altitude.

At Horns Rev, Denmark, potential collision risk was identified for foraging northern gannets (possibly also for terns and skuas *Stercorariidae* and possibly for northern gannets, great cormorants, terns and gulls in flight (Noer *et al.* 2000). Most of the species present have high annual survival rates and low productivity and so the consequences of collisions are potentially more significant than they would be for species of short longevity and high breeding productivity.

A combination of visual and radar studies in Germany (Hüppop *et al.* 2003, cited in ICES 2003) showed that considerable migration over the sea occurs at heights that bring birds into risk of collision with wind turbines, especially during low visibility (fog, rain, darkness) when birds fly at lower altitude. The majority of bird movements were observed during relatively few nights, which has led to the suggestion that forecasting occasions of heavy migration at low altitude could be used to trigger shutdown of turbines. This presupposes that it is the rotating blades that are responsible for collisions, but collisions also occur with the turbine towers, so whilst such a measure might reduce the potential for collision mortality, it does not remove the need to avoid the siting of windfarms in important migration areas.

As part of the assessment of impacts of the windfarms at Utgrunden (seven offshore wind turbines built in 2000) and Yttre Stengrund (five offshore wind turbines built in 2001), in the southern Kalmarsund, Sweden, comparative studies of migration through the area were made using a combination of visual observations and radar recordings (Pettersson 2001). The Kalmarsund is a very important migration route for common eiders (150-200 000 individuals during autumn), barnacle goose *Branta leucopsis* (50-100 000), brent goose *Branta bernicla* (10-20 000) and European white-fronted goose (10-15 000), together with a large number of other ducks and cormorants. The principle study species was common eider. After tailwinds, weak headwinds were preferred wind conditions for flight. In headwinds, the birds tended to fly closer to the western shore of the Kalmarsund, instead of further out over open water, bringing them into the area of the proposed Yttre Stengrund windfarm, but away from the Utgrunden windfarm. Twenty percent of the total autumn 2000 eider passage was estimated to have flown through the area of the planned Yttre Stengrund windfarm and over 30% (*ca* 65000 eiders) on the night of particularly large passage in late October.

Radar studies identified considerable nocturnal movement, especially during late evening, with up to 20% of the daytime levels recorded (Pettersson 2002). The patterns of flight were similar to those in daylight; eider flocks flew around either side of the turbine clusters. During misty conditions, birds continued to pass through the Sound, with geese thought to move on a broad front, although there were too few observations to provide conclusive results. The main limitation of the type of radar used, was that it was only able to detect larger flocks, at least 80 eiders for example, and was poor at detecting movement just above the water surface, due to scatter attributable to waves. Furthermore, rain caused interference in the display too.

Low-flying flocks of eiders were rarely seen to pass within 500 m of the wind turbines during daytime, and avoidance behaviour was observed, with some birds altering direction 3-4 kms before reaching the Utgrunden windfarm to fly around it (Pettersson 2002). Pettersson (2002) thought that the observed change in migration route through the Sound after windfarm construction might be attributable to the presence of the turbines. Clearly, in an area with large numbers of migrating birds passing through and likely to change route and altitude in response to the prevailing weather conditions too, there is a risk of collision, especially in a scenario of multiple windfarms and given the continuation of movement in fog. Pettersson (2002) also observed a potential barrier effect as the majority of flocks of diurnally migrating eiders flew around the outside of the wind cluster, thereby avoiding the turbines. However, flocks of cranes and geese were seen passing above the wind turbines at altitudes of 120-200 m, bringing them into potential collision course as they cross the Sound, especially during misty conditions when a near miss of the meteorological mast by white-fronted geese was observed. The majority of flights recorded were within the height band occupied by the wind turbines. No collisions have been observed, but it is difficult to judge whether this means collisions have not occurred on the basis of visual observations and limited radar tracking.

Satellite tracking of migrating whooper swans has confirmed the importance of weather and light conditions to the birds when making sea crossings (Pennycuick *et al.* 1999). Most birds flew low, often landing on the water and only moved on when visibility was greater than 2 km and when the altitude of the sun or the moon was at least 4^{o} above the horizon. Larsen & Clausen (in prep.) studied the daily movements of whooper swans between their coastal roosting sites and inland feeding areas. Most flocks flew at 5-30 m above the ground, potentially bringing approximately 10% to 30% within the height of the rotor swept area for medium and large turbines, respectively. The authors suggest that the risk of collision was greatest during evening flights, but likely to vary with season, depending on the light levels at the time of their evening flight. The paper acknowledges the likelihood of avoidance manoeuvres, and other work would indicate that this is more likely for resident birds than for migrants. Swans have a high hit-wire index (Rose & Baillie 1989), on account of their large body mass and slow manoeuvrability and are susceptible to collision with a variety of structures including powerlines (Butler 1999) and wind turbines.

– Lighting

Lighting of turbines has the potential to attract birds, thereby potentially increasing the risk of collision (Winkelman 1992b), as demonstrated by the large number of collisions recorded over just one night in Sweden with a single turbine that was out of operation but illuminated (Karlsson 1983). Lit structures can increase collision risk, especially in conditions of poor visibility. There have been notable large collision mortality events at a wide range of lit structures as a result of nocturnal migrant songbirds, flying at low altitude in rain and mist, being disorientated by lights (e.g. Elkins 1983, Cochran *et al.* 1958, Case *et al.* 1965, Cunningham 1965, Herbert 1970, Weir 1976, Maehr *et al.* 1983, all cited in California Energy Commission 1995, Manville 2000 cited in Erickson *et al.* 2001).

However, lighting will be required for navigation, e.g. a flashing white light at 10 m above sea level on the turbines for ships and a permanent or flashing light at the top of the turbines for aircraft (Noer *et al.* 2000; UK Civil Aviation Authority *pers comm*). Intermittent lights may reduce the risk of attraction (Richardson 2000, see also account in ICES 2003). Erickson *et al.* (2001) suggest that lighting is the single most critical attractant, leading to collision with tall structures. It is possible that a cluster of turbines will reduce the single point source attraction and is likely to provide a more diffuse light distribution. It has been suggested that the potential hazard arising from a bright light source could be reduced by shielding, but this requires testing to meet the combined requirements of navigational safety without introducing an unacceptable collision risk for birds either (discussion point at Fuglsø conference, Denmark, November 2001). This requires further study, and is particularly important in relation to locations where there are concentrations of migratory birds.

2.3 Birds and windfarm offshore

There follows a discussion of the information requirements and availability for assessing potential effects of windfarms on birds at sea.

The species groups of most conservation concern offshore are seabirds, waterbirds (notably waders and wildfowl) and migrating passerines. Information is variable about concentrations of birds offshore and especially of migratory movements. There are data on the broad distributions of seabirds in coastal waters in all months of the year, from the European Seabirds at Sea (ESAS) programme (e.g. Skov *et al.* 1995). Birds may be present in large numbers but at low densities over large areas of sea. However, there is a lack of detailed understanding about local distribution, variability of numbers and the underlying determinants of their timing of occurrence in a given location, e.g. scoters *Melanitta spp.* Food supply is clearly important, and more information is needed about distributional patterns seasonally and between years and how offshore food supplies are exploited.

Currently, whilst it is possible to give an indication of some areas of high, medium or low conservation concern, information is limited. For example, with respect to the UK, there is a need for seabird information for areas of the North Sea and Irish Sea not previously covered. In particular, cover is limited in the coastal zone, shallow waters, although in recent years, aerial surveys have been undertaken in the Irish Sea, Greater Thames and Greater Wash areas of the UK to improve the level of information. Cold weather refuges also need to be identified. Information on distributions and density over time will enable the identification of qualifying areas for statutory designation and will facilitate sensitivity mapping for strategic environmental assessment (SEA).

The distance offshore at which offshore windfarms are sited is likely to be important. Generally, siting them close inshore, depending on the location, is likely to increase the potential for intercepting flight paths by birds moving between feeding areas (e.g. scoters), feeding and roosting (e.g. waders and wildfowl) or breeding and feeding areas (e.g. seabird colonies) and larger-scale movements along the coast or migration landfall or departure. Knowledge of local, inshore movements, in different weather conditions, and the proportion coinciding with the height of the turbine blades, are also essential for assessing the potential for conflict with wind turbines, either as a result of collision or barriers to movement. Some species have locational constraints, for example distribution of shellfish prey and physiological water depth limitation for diving seaducks, such as common scoter.

Further offshore, large concentrations of birds are most likely in response to food availability, e.g. at tidal upwellings which concentrate plankton and shoals of fish, around fishing vessels, and when birds are rafting during feather moult etc. Pinpointing key locations offshore will be necessary to understand the possible links between seabird nesting colonies and their feeding areas. There is some documentation on foraging distances around the UK by breeding seabirds to assist in determining potentially sensitive areas further offshore (BirdLife International 2000). Winter and migratory distributions, and their determinants, are more difficult to assess.

Most studies to date have been of windfarms comprising small wind turbines (≤500 kW), often in small clusters (1-10) and onshore. The development of the offshore industry is likely to see substantial increases in the size of turbines (already 2-3 MW installations and prospect of 5 MW in a few years time) and clusters, which may have different implications, although relatively fewer large turbines would be needed for a given energy output. This needs to be taken into account when designing studies and when comparing studies. Larger turbines may have the advantage of greater visibility, enabling birds to judge their passage through a windfarm more easily. Conversely, larger turbines may pose more of a problem because of the greater height range through which the rotor blades travel. This conundrum was recognised by Gill *et al.* (1996), and requires investigation.

– Disruption of seabed and prey availability offshore

Prey availability may be affected. Construction and decommissioning will potentially damage the benthos and disrupt sediments locally, both of which are likely to lead to changes in the invertebrate fauna and fish stocks, for example as a consequence of the effects of electromagnetic fields around under-sea power cables. There is particular concern about the damage to benthic communities that may take months or even several years to recover, arising from cable installation especially by trenching, installation of foundations and disposal of excavation spoil. This in turn could reduce food availability for birds, at least in the short term. There will be limited exposed surface for marine infauna to colonise, if drilled or piled structures are used, but where offshore reefs do form on the rock armour around turbine bases, they may not be compatible with the local fauna.

There is evidence of stable or improved food availability for birds in studies by the Dutch and Danes as the fishery exclusion zones around operational offshore windfarms acted as refuges, thereby improving shellfish stocks in those areas and encouraging more feeding birds (Guillemette *et al* 1997). However, there is the potential for increased bird collision risk if birds are attracted into the windfarm by greater food abundance, for example terns and gannets whose plunge-diving feeding behaviour may bring them into the rotor swept area of turbines. Furthermore, fisheries refuges may nonetheless attract fishing vessels into the area.

Sandbanks that are important feeding locations may present points of conflict, especially where large numbers of turbines are proposed such that much/all the area is likely to be occupied by a windfarm. Shallow water areas are potential fish spawning grounds, favoured by sandeels *(Ammodytes* spp*, Hyperoplus lanceolatus),* and locations of mussel *Mytilus* spp beds etc. and so can be important to feeding seabirds, seaducks and to fisheries. Several offshore windfarms are being proposed in shallow waters, often on sandbanks, e.g. Kish and Arklow Banks in Eire (BirdWatch Ireland *pers. comm.*, Coveney & Phalan 2001). As larger turbines are developed, there is the potential to move into deeper water, although cost-benefits still may lead to a preference for shallow waters.

2.4 Habitat loss or damage

Loss of or damage to habitat, resulting from windfarm infrastructure, is not generally perceived to be a major concern for birds outside designated or qualifying sites of national and international importance for biodiversity, depending on local circumstances and the scale of land-take required for the windfarm and associated infrastructure. The cumulative loss of or damage to sensitive habitats may be significant, especially if multiple, large developments are sited in such locations, e.g. on sandbanks in shallow waters or on peatlands. Furthermore, direct habitat loss may be additive to disturbance exclusion.

Onshore infrastructure, including access roads, substations, turbine bases etc. will involve land take, which could be considerable in remote upland areas or in steppe grasslands, where birds may suffer fragmentation and a restriction of the available habitat, for example as a result of new roads. The opening of new roads in such remote locations might also represent an important additional impact, for example enabling generally increased access. Local hydrology may be interrupted in sensitive habitats, e.g. peatland soils, by turbine anchorage and access roads. Direct loss of habitat is potentially important in forest habitats, where windfarms and their associated infrastructure require removal of the vegetation.

Offshore, generally, direct habitat loss is small-scale, primarily for turbine bases and cables at sea. The type of anchorage used (gravity base, drilled or piled monopiles, suction base) will affect the scale of habitat loss.

Offshore changes in sediment transport around the fixed structures may have implications for coastal erosion and sea defences. This is an unknown impact. It may be of only local, if any significance, depending on the size of the windfarm and the distance offshore. However, turbines sited in areas of particularly dynamic sediments may interfere with natural processes, with consequent implications for benthos and fish populations. Habitat loss, change or degradation, arising from changes in sedimentary processes, may be significant if large numbers of turbines are sited on sandbanks that are valuable foraging locations. This in turn may affect food availability for birds. For example, accretion around turbines located on sandbanks may raise the height of substrate so that its exposure time is greater, altering its suitability for sandeels. The hydrological and geomorphological implications of siting fixed structures on these substrates need to be assessed as well as the ecology of these areas. In particular, the cumulative effects on hydrology arising from multiple, large-scale windfarms is unknown.

2.5 Other issues

2.5.1 Platforms for roosting, nesting, colonisation

Turbines may offer roosting or nesting sites for birds. Access walkways and substations may attract birds to settle, bringing them into close proximity to the turbines. Thelander & Rugge (2000) found that wind turbines were the most frequently used perching structures in their study at Altamont, California, but many of the turbines were early installations whose designs have been superseded. Large gulls are attracted to loaf on top of the flat-topped nacelles in the Tunø Knob windfarm in Denmark (pers. obs.) and cormorants have been observed on landing platforms at offshore installations (Sundberg, *pers. comm.*). These aspects will require further study to clarify the extent of use and whether or not there is a problem.

2.5.2 Pollution offshore

This is likely to be of minimal concern, but relates mainly to maintenance and cleaning agents. Strict procedures for the use and disposal of any substances should be adhered to. A voluntary code of practice for the offshore industry is proposed, similar to that adopted by the oil and gas industry (Metoc 2000). It will be important to determine the effectiveness of a voluntary code and, if necessary, to introduce stricter measures. There is also the risk of release of toxins from sediments during construction and cabling, and due to scour etc.

3. Environmental assessment and site selection guidelines

This part of the report provides headline guidance on criteria for environmental assessment and precautions for site selection of windfarms. More information on environmental assessment criteria is provided in Annex 1 to the report, together with an overview of study methods appropriate for environmental assessments of windfarms.

Further information on site selection precautions can be found in the joint English Nature, Royal Society for the Protection of Birds, World Wide Fund for Nature – UK and British Wind Energy Association document on ‘Windfarm Development and Nature Conservation’ (WWF-UK 2001). This also provides useful guidance on how to respond to windfarm proposals, especially in relation to site protection status. Although written from an England perspective, it has relevance elsewhere.

3.1 Criteria for Environmental Assessment

Environmental Assessment is an essential tool that identifies the environmental effects and impacts of plans, projects or proposals on the environment, and potential measures to avoid these. The quality of the assessment is paramount, to enable an informed and objective decision to be made on the available information (i.e. existing and collected specifically for the environmental impact assessment (EIA)). There is considerable support for wind energy as an environmentally benign source of energy. Nonetheless, stringent environmental assessment is just as important for wind energy as for other developments to ensure that it is sited optimally and to avoid or at least minimize any adverse impact.

In relation to wind energy, the following criteria should be met:

– All wind energy projects should be screened to determine whether they are likely to have a damaging effect on wild birds and the wider environment[1] (see Annex 1).

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[1] In EU states, by reference to the selection criteria set out in Article III of Directive 85/337/EEC on the *‘Assessment of certain public and private projects on the environment’*, as amended by Directive (97/11/EC), or the use of similar criteria in countries where this is inappropriate. Within the EU, if a project is likely to have a significant effect on a Natura 2000 site (as designated under the Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna (92/43) or the Directive on the Conservation of Wild Birds

- If screening determines that the project should be subject to an EIA, then this should be carried out to the highest standards using current best practice, for example as set out in Annex 1 to this document.
- In the offshore environment, all wind energy projects should be subject to EIAs unless and until an adequate information base exists to permit screening.
- EIA must be initiated early in the project planning process and should incorporate full consultation with relevant government bodies and Non-Governmental Organisations (NGOs).
- The EIA must assess the potential effects of the turbines and all associated infrastructure including pylons, cables, substations and access routes. Advice on significance of effect can be found in the Annex 1 to this document.
- The EIA should include, as a minimum, a 12- month baseline field survey to determine the bird populations that use the study area during an annual cycle. The baseline data collection is also important to enable a risk assessment.
- The results of the baseline surveys should be applied to the consideration of different proposal options. Options should include different site locations and different layouts and numbers of wind turbines, in order to prevent or at least minimise any potentially adverse effects.
- If there are any other projects (other windfarms or other developments) which have been developed or are being proposed in the area, then the EIA must take into account any cumulative effects on birds that may arise from the windfarm development in conjunction with these other projects (see Annex 1).
- If potential or actual harmful effects to wild birds or their habitats are identified, then the EIA must address these. If the impact can be avoided, mitigated or remedied by suitable avoidance or mitigation measures, the EIA should identify these measures, as set out in Annex 1 to this document[1]. In addition, the EIA should identify compensation measures to compensate for any residual damage, in the event that a potentially/actually damaging windfarm nonetheless is consented.
- Suitable pre- and post-development monitoring of impacts on birds must be carried out, using the Before-After Control-Impact (BACI) approach. Details of the monitoring programme must be set out in the wind energy project EIA. Monitoring feedback will inform whether further mitigation measures are required in the operational phase of the project concerned, if outcomes differ from those predicted by the EIA. Additionally, this information will help inform future wind energy development. Post-construction monitoring needs to continue for long enough to distinguish short- and long-term effects and impacts, and to enable these to be satisfactorily addressed (see Annex 1 for monitoring framework).

(79/409)), then an Appropriate Assessment, as set out in Articles 6(3) and 6(4) of Directive 92/43 will also be required.

[1] Within the EU, much of criteria 1, 2, 5 & 6 should already be common practice, as the principles are set out in Directive 85/337/EEC as amended by Directive 97/11/EC.

- Poor quality EIAs, or lack of information, must not be permitted to lead to planning approval on the grounds of no demonstrable effect. Adequate EIAs and planning decisions can be made only on the basis of robust data and rigorous assessment.

3.2 Sensitive Species

On the basis of the literature review, species' conservation status and more than ten years collective experience by the BirdLife partners, the following species groups and example species are considered to be particularly sensitive, or potentially so, to windfarms (disturbance displacement, barriers to movement, collision, habitat loss or damage), although in many cases there is a lack of impact studies to date. Thus, they are likely to be focal species for detailed environmental assessment and research. This list is indicative rather than comprehensive. There are many species for which there is either no information, or no conclusive information, to date. Focal species are likely to be site and issue specific and may change in the light of further research or change in conservation status (see next page).

3. 3 Precautions for site selection for windfarms

Many of the potential conflicts between wind energy developments and wild bird populations can be avoided by informed site selection. The following precautions and future needs should be applied to windfarm development:

- Adverse impacts on wildlife must be avoided by full evaluation of suitable alternatives, appropriate siting and design (see Annex 1, section on mitigation).
- There is a strong consensus that location is critically important to avoid deleterious impacts of windfarms on birds. There should be precautionary avoidance of locating windfarms in statutorily designated or qualifying international (e.g. Natura 2000 – SPAs & SACs, 'Ramsar sites', Emerald Network and Important Bird Areas (IBAs)) or national sites for nature conservation[1], or other areas with large concentrations of national sites for nature conservation[2], or other areas with large concentrations of birds, such as migration crossing points, or species identified as being of conservation concern. The favourable conservation status of habitats and species in these areas is a central tenet to their designation, requiring demonstration of compatibility with this aim by any proposed development. The weight of

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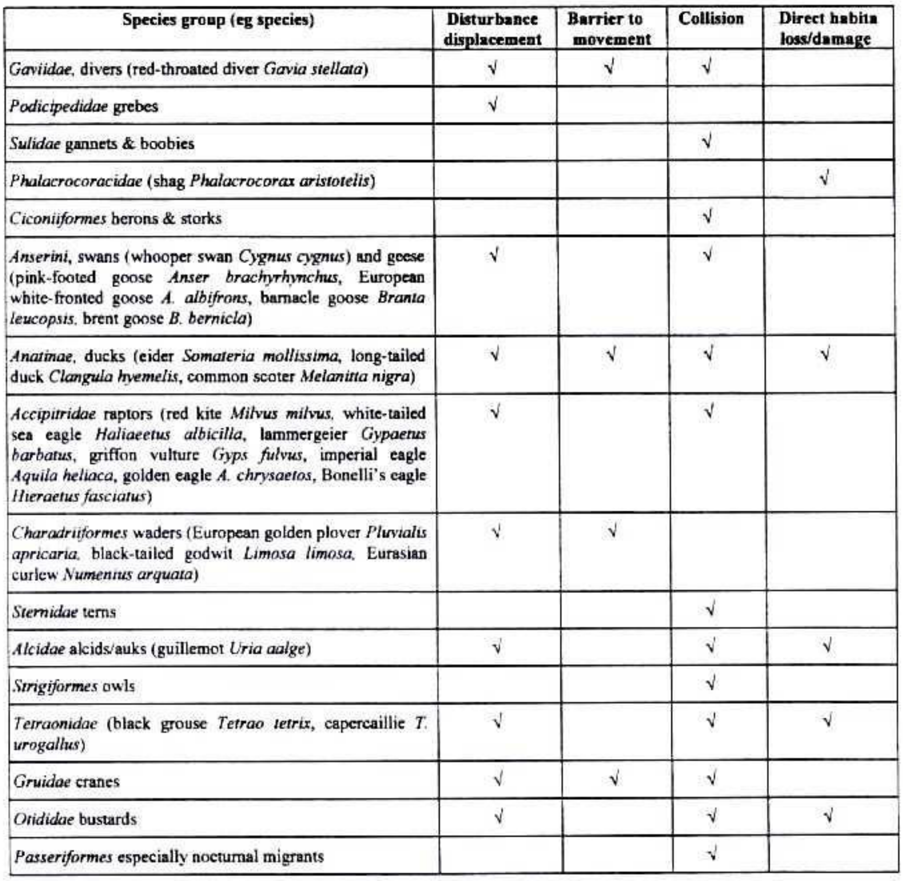
[1] In relation to precautions 2 & 3, there is an urgent need for statutory designation of marine nature conservation areas. NABU, the German BirdLife partner has lodged a complaint to the European Commission in response to the proposed offshore windfarm at Butendiek, on the grounds that it is located in the Eastern German Bight IBA, an area that qualifies for designation under the EU Birds and HabitatsDirectives, but is overdue designation, and the precautionary avoidance of such areas for development.

[2] In relation to precautions 2 & 3, there is an urgent need for statutory designation of marine nature conservation areas. NABU, the German BirdLife partner has lodged a complaint to the European Commission in response to the proposed offshore windfarm at Butendiek, on the grounds that it is located in the Eastern German Bight IBA, an area that qualifies for designation under the EU Birds and Habitats Directives, but is overdue designation, and the precautionary avoidance of such areas for development.



Species group (eg species)	**Disturbance displacement**	**Barrier to movement**	**Collision**	**Direct habita loss/damage**
Gaviidae, divers (red-throated diver *Gavia stellata*)	√	√	√	
Podicipedidae grebes	√			
Sulidae gannets & boobies			√	
Phalacrocoracidae (shag *Phalacrocorax aristotelis*)				√
Ciconiiformes herons & storks			√	
Anserini, swans (whooper swan *Cygnus cygnus*) and geese (pink-footed goose *Anser brachyrhynchus*, European white-fronted goose *A. albifrons*, barnacle goose *Branta leucopsis*, brent goose *B. bernicla*)	√		√	
Anatinae, ducks (eider *Somateria mollissima*, long-tailed duck *Clangula hyemelis*, common scoter *Melanitta nigra*)	√	√	√	√
Accipitridae raptors (red kite *Milvus milvus*, white-tailed sea eagle *Haliaeetus albicilla*, lammergeier *Gypaetus barbatus*, griffon vulture *Gyps fulvus*, imperial eagle *Aquila heliaca*, golden eagle *A. chrysaetos*, Bonelli's eagle *Hieraetus fasciatus*)	√		√	
Charadriiformes waders (European golden plover *Pluvialis apricaria*, black-tailed godwit *Limosa limosa*, Eurasian curlew *Numenius arquata*)	√	√		
Sternidae terns			√	
Alcidae alcids/auks (guillemot *Uria aalge*)	√		√	√
Strigiformes owls			√	
Tetraonidae (black grouse *Tetrao tetrix*, capercaillie *T. urogallus*)	√		√	√
Gruidae cranes	√	√	√	
Otididae bustards	√		√	√
Passeriformes especially nocturnal migrants			√	

evidence to date indicates that locations with high bird use, especially by protected species, are not suitable for windfarm development.

- Placement of windfarms in suitable industrial areas, harbour complexes and on agricultural land should be considered in addition to more traditional upland and coastal sites.
- Strategic Environmental Assessment (SEA) should inform strategic site selection of windfarms.
- Offshore, there is a limited extent of shallow water areas to accommodate the burgeoning wind energy industry, especially in the light of nature conservation sensitivities, within and out with protected areas. Moving turbines further offshore in some areas needs to be considered.

3.4 Recommendations

There is an urgent need for marine protected areas to be identified and designated, so that informed decisions can be made on the location of offshore windfarm development.

Research and monitoring should be implemented by national governments and the wind energy industry, in consultation with relevant experts, to improve our understanding of the impacts of windfarms. This will be an iterative process that will inform decision-making, appropriate site selection and windfarm design. The results of research should be published in international scientific journals, including a summary, preferably in English, to ensure wider dissemination.

Research and monitoring requirements encompass the following: effects and potential population level impacts on birds of disturbance displacement, barriers to movement, collision mortality and habitat loss or damage; effectiveness of different windfarm layout and turbine design to provide mitigation.

National governments must undertake Strategic Environmental Assessment (SEA)[1] of all wind energy plans and programmes that have the potential for adverse impacts on birds in their country. If there are potential trans-boundary effects, then international co-operation with other governments should be sought when undertaking the SEA. The scale of SEA should also be determined by consideration of the likely biological scale of impacts as well as jurisdictional boundaries.

Specifically, these SEAs should include indicative mapping of bird populations, their habitats, flyways and information about migration routes, where this is known, and an assessment of the plan's probable effects on these, to aid decision-making.
As part of effective regional planning, there is a need to identify species and areas of concern, to map potential and no-go locations for wind energy development on the basis of nature conservation concerns, for example avoidance of focal points for migration crossings. This may require the collection of additional information, especially offshore. Such information requires regular review and updating as necessary to determine whether there have been changes in distribution or patterns of movement.

There need to be incentives to ongoing technological development to maximise efficiency of wind turbines and to reduce dependency on the limited shallow water habitats offshore.

There is a need for best practice guidance on standard study methods, to inform the EIA process, expanding on the information given in Annex 1.

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[1] As set out in Directive 2001/42/EC of the European Parliament and of the Council, 27 June 2001 'on the assessment of the effects of certain plans and programmes on the environment'.

This report has not looked in detail at individual case studies to evaluate examples of conflict resolution, case law, or trends in casework throughout the Council of Europe area. This may be a useful subject for further study.

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MME BirdLife Hungary;
Naturschutzbund Deutschland (NABU);
BirdLife Belgium;
Norsk Ornitologisk Forening (NOF);
Royal Society for the Protection of Birds (RSPB);
Sociedad Española de Ornitologia (SEO/BirdLife);
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6. Useful Websites

Alterra, formerly IBN-DLO www.alterra.nl

American Wind Energy Association (AWEA) http://www.awea.org/

BirdLife International www.birdlife.net/sites/index.cfm

BfN (Bundesamt für Naturschutz) http://www.bfn.de/

BMU (Bundesministerium für Unwelt, Naturschutz und Reaktorsicherheit) www.bmu.de/en/ [Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

BSH (Bundesamt für Seeschifffahrt und Hydrographie) http://www.bsh.de/en/index.jsp

Bureau Waardenburg www.buwa.nl

British Wind Energy Association (BWEA) http://www.bwea.com/

California Energy Commission www.energy.ca.gov/reports

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) www.wcmc.org.uk/cms/ including the African Eurasian Waterbird Agreement (AEWA) www.unep-wcmc.org/AEWA/eng/intro.htm www.wcmc.org.uk/cms/

Conservation of European Wildlife and Natural Habitats (Bern Convention) http://www.coe.int/t/e/Cultural_Co-operation/Environment/Nature_and_biological_diversity/

Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran 1971), as amended by protocol of 1982. (Ramsar Convention) www.ramsar.org

The Crown Estate (UK) www.crownestate.co.uk

COWRIE (Collaborative Offshore Wind Research Into the Environment) http://www.crownestate.co.uk/estates/marine/windfarm/cowrie.shtml http://www.crownestate.co.uk/estates/marine/windfarm.shtml

Instituut voor Natuurbehoud www.instnat.be

UK Department of Trade & Industry www.dti.gov.uk/renewable

UK Round 2 Offshore Wind Energy: http://www.dti.gov.uk/energy/renewables/technologies/offshore_wind.shtml

DMU (Danmarks MiljØundersØ) National Environmental Research Institute, Denmark www.dmu.dk

European Wind Energy Association (EWEA) http://www.ewea.org/

Horns Rev Windfarm, Denmark http://www.hornsrev.dk/

ICES http://www.ices.dk/reports/occ/2003/ International Council for the Exploration of the Sea

National Wind Coordinating Committee, USA www.nationalwind.org

NWCC site map http://www.nationalwind.org/sitemap.htm

National Renewable Energy Laboratory (NREL), USA www.nrel.gov/wind/

Most reports are accessible via the Office of Science and Technical Information http://www.osti.gov/bridge/search.results.jsp?queryId=2&start=0&

UK Offshore Wind www.offshorewindfarm.co.uk

University of Lund, Sweden bird migration studies

http://orn-lab.ekol.lu.se/birdmigration/
http://www.tu-berlin.de/~lbp/schwarzesbrett/tagungsband.htm

Web-based windfarms & birds discussion group

http://groups.yahoo.com/group/wind_turbines_birds/

Appendix 1

Environmental Assessment

Supplement to Chapter 3, Environmental Assessment
and Site Selection Guidelines

Key European Union legislation

In relation to environmental assessment, there are two key pieces of legislation that apply, or will apply, in the European Union:

- Directive 85/337/EEC on *Assessment of certain public and private projects on the environment* (EIA Directive), as amended by Directive 97/11/EC.
- Directive 2001/42/EC The assessment of the effects of certain plans and programmes on the environment (SEA Directive).

These have important roles to play in directing the assessment of environmental impacts of windfarms.

Additionally, in the EU, the following Directives inform decision-making procedures for development affecting 'Natura 2000' sites (SPAs & SACs):

- Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna (Habitats Directive);
- decision making processes in relation to development that is likely to have a 'significant effect' on a Natura 2000 site are set out in Articles 6(3) and 6(4). For guidance on interpretation on Article 6 of the Directive, see 'Managing Natura 2000' (European Commission 2000);
- Directive 79/409/EEC on the Conservation of Wild Birds (Birds Directive);
- Annex I of the Birds Directive and Annex IV(a) of the Habitats Directive also outline species which receive special protection outside the Natura 2000 network under the Directives;
- also, Conventions on the Conservation of Migratory Species of Wild Animals (Bonn Convention), including the African Eurasian Waterbird Agreement (AEWA), the Conservation of European Wildlife and Natural Habitats (Bern Convention), and the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar, Iran 1971), as amended by protocol of 1982 (Ramsar Convention) all confer international responsibilities on signatories.

Screening

Within the EU, selection criteria for screening for environmental impact assessment (EIA) are set out in Directives 85/33/EEC and 97/11/EC. Outside the EU, broadly, screening decisions should take into account:

- the scale of the windfarm and whether there is potential for cumulative effects with other projects;
- the environmental sensitivity of the area likely to be affected by the windfarm;
- the extent of the impact of the windfarm, its magnitude, probability, duration, frequency and reversibility.

Environmental Impact Assessment

Environmental Impact Assessments (EIAs) need to quantify and interpret the potential effects and impacts on nature conservation, necessitating pre-construction baseline surveys and post-construction monitoring of numbers and distributions of species (e.g. marine infauna and birds offshore, using BACI approach), as well as studies of use of areas by focal species. The latter will include an assessment of collision risk and, post-construction assessment of collisions. The key avian requirements of the EIA are to determine how many birds might be displaced by the windfarm, and the potential mortality arising from collisions. Post-construction monitoring needs to be of sufficient duration to distinguish short- and long-term effects and the potential for habituation:

EIA for wind energy projects needs to be of the highest standard – independence, reliability and accuracy of monitoring and interpretation are essential.

There is a need to develop common standards in terms of the scope of EIAs and to implement sound monitoring programmes from the outset. Early consultation with the relevant government departments and NGOs is essential to establish this framework. It is envisaged that the developments, offshore in particular, carried forward in the next few years will set the blueprint for future development.

Standardised study methods should be applied, although some site-specific or species specific sampling protocols may be necessary, e.g on large versus small sites, targeted survey methods for some species.

Co-operative studies are of considerable value to enable geographically and biologically meaningful baseline information to be collected within which individual windfarm studies can be incorporated. This is especially true in areas with multiple proposals.

Lack of knowledge, especially offshore, hampers the ability to objectively assess the impacts of windfarms. Information from auto-ecological studies, where available, needs to be incorporated to aid the interpretation of impacts. There is a need for research into appropriate study methods, especially offshore. Population modelling may be useful for assessing population level impacts for selected species, e.g. for offshore one might concentrate on the shallow marine coastal zone and scoters.

At a strategic level, governments and NGOs should co-operate to identify:

- areas which are likely to be unacceptable in conservation terms for development and allow for a buffer around these to minimise impacts on the conservation area;
- areas of concern requiring further information to determine their status;

- areas where windfarms are not considered likely to pose a threat to conservation.

It is important to identify all the existing constraints/restrictions to locating wind energy projects.

Impacts may operate at different spatial scales, from the site level (cf. designated sites) to the flyway level. The effects of local changes in abundance and distribution of birds in relation to windfarm construction may lead to changes in demographic processes and consequently may lead to population level impacts. This necessitates a population level or flyway approach, including consideration of cumulative impacts at these scales. Individually, windfarms may have little effect on bird populations, but cumulatively the implications may be very different, whether the problem arises from direct mortality or from displacement owing to disturbance. Integrated SEA across state boundaries and across development types will be required to enable these large scale impacts to be determined.

Significance of impact

The significance of a particular impact is not something that can be easily codified in best practice guidance. Significance will vary depending on the circumstances of the case in question, including relative impact:

- magnitude,
- type,
- extent,
- duration,
- intensity,
- timing and
- probability.

For example, observed effects of a windfarm may or may not be significant and lead to potential adverse impacts. It is important that the distinction is made as knowledge improves our ability to do so. Displacement is a potential effect of wind turbines. Whether it leads to an impact depends on the scale of displacement at the site level and possible impact at the population level.

Significance will also depend on the 'receptor' of the impact – in this case the bird species affected (their population size, distribution, range, reproduction strategy, lifespan, etc.). It is important that these attributes are considered in assessing the significance of an impact and described as fully as possible in the Environmental Statement.

As an example, the scale. Large windfarms, especially comprising large turbines, are likely to have a different significance of effect to small windfarms due to the potential synergistic effects of scale. Large windfarms have the potential for a much larger barrier effect to bird movements or exclusion effect of disturbance, depending on location and layout of turbines.

Significance of effect cannot be judged only on an individual project basis. Whilst displacement and collision mortality may or may not be detrimental at a site level, cumulatively with other projects they may lead to a population level impact. Consideration of these cumulative effects is considered in the following section.

Controls associated with statutorily protected sites (such as Natura 2000 sites in the EU), may dictate the significance of impacts when it comes to decision-making. For example, in the case of proposals that affect designated and qualifying Natura 2000 sites, whether or not an effect is found to be adverse will be critical in any subsequent decision-making process. See *Managing Natura 2000 sites* (European Commission 2000) and notes in the next section on proposals that affect Natura 2000 sites.

In all cases where there is uncertainty as to the significance of an impact, the precautionary principle should be applied to decision-making.

Cumulative effects

This is an essential, but often inadequately covered, component of windfarm EIA. Cumulative effects may arise from multiple windfarm proposals or from the windfarm proposal and other types of development. A strategic impact assessment should include all projects that have been developed, or are planned for the area surrounding the proposed windfarm site[1]. Using collision mortality for illustration, effects are likely to lie somewhere in the continuum between the extremes of 'additive' – increasing overall mortality – or 'compensatory' – replacing other causes of mortality. Sub-lethal effects (such as loss of body condition, from avoidance behaviour or loss of habitat) are more insidious than direct mortality and there may be a delay before any population-level impact is detected.

The key questions are: at what point do accumulated habitat loss (including effective habitat exclusion due to disturbance) and collision mortality impact on population size and distribution?

These are not straightforward questions to address and may be most effectively considered at a strategic level, hence the need for Strategic Environmental Assessment (SEA). Strategic Environmental Assessment requires both sector-level and cross-sector assessment of cumulative impacts (SEA Directive). National and international Government-led programmes are likely to be the only satisfactory way to deliver strategic overviews, including fundamental monitoring and the necessary research.

The avoidance, mitigation and compensation hierarchy

Adverse impacts should be avoided wherever possible. If adverse effects or impacts cannot be avoided, then suitable mitigation measures should be employed to reduce or

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[1] Cumulative impact assessment (for EIA), should not be confused with the 'in combination' requirement when deciding whether a project is likely to have a significant effect on a Natura 2000 site. See *'Managing Natura 2000 sites'* (European Commission 2000) for guidance on this.

remedy them. Finally, adverse impacts that cannot be mitigated to require compensation, if the project proceeds.

– Mitigation

Where a detrimental impact is identified, or is considered to be a significant risk of a detrimental impact, mitigation measures to avoid, reduce or remedy the impact should be implemented wherever possible. Mitigation by appropriate siting and design is of key importance.

Mitigation is likely to take the form of modifications to the layout of the windfarm, in terms of orientation of turbines, spacing and location. There are research findings which indicate that modifying these factors can reduce collision risk, but further research is necessary to test mitigation options and their effectiveness. Aspects of turbine design also may be modified in mitigation, e.g. intermittent rather than continuous navigation lighting. Again, the effectiveness of this measure requires testing (and assessing in terms of acceptability for navigation).

Other aspects of mitigation relate to the timing of construction works and methods applied. Modifications to aspects of associated infrastructure, e.g. access roads, may be applicable too.

Where mitigation is proposed to alleviate damaging impacts, the effectiveness should be assessed. Any mitigation measure requires monitoring to determine its effectiveness against prescribed targets and a contingency plan in the event of it not meeting those targets. For example, periods of shutdown may be advocated, but the suitability of temporary shutdown as a mitigation measure is questionable, as the turbines may pose a hazard in poor flying conditions even when not operational, owing to the removal of auditory cues.

– Compensation

Compensation should be a last resort and should only be considered if mitigation measures will not reduce adverse impacts to an acceptable level and the project is consented as the benefits of the proposal are seen to outweigh the environmental costs. Also, it may be very difficult to achieve, e.g. compensation for habitat loss in the offshore environment.

Compensation for habitat loss should offer comparable habitat in the vicinity of the development. This should normally be in place prior to the impact wherever possible[1]. This includes securing all necessary legal and financial measures to secure the compensation. As for mitigation, monitoring should be put in place to check that the compensatory habitat is performing as planned. Suitable mechanisms should be agreed when consent is granted to remedy any future shortfall in performance of compensatory habitat.

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[1] *Managing Natura 2000 Sites'* also advocates this in relation to development that will have an adverse effect on a Natura 2000 site.

Post-construction habitat restoration or enhancement of the site, together with environmentally sensitive management of the site may be beneficial. However, habitat enhancement within the windfarm area may require further associated measures to avoid increasing the risk of collision. Compensation for collision mortality may involve the development of a species management plan to increase the population elsewhere so as to more than offset increased mortality due to collisions.

It should be noted that compensation for adverse impacts on a Natura 2000 site (within the EU) only comes into play if it is proven that there are no alternative solutions to the proposal, and that it must be carried out for imperative reasons of overriding public interest (see Articles 6(3) & 6(4) of Directive 92/43/EEC). In this case, compensation measures must be put in place to ensure that the overall coherence of Natura 2000 is protected.

Windfarm study protocols

The appropriate sampling design and duration of research and monitoring will depend on the location, species present, their sensitivity and conservation importance and the size of the proposed windfarm development (Langston 2002). Early and continued consultation with the relevant conservation agencies, NGOs and experienced researchers will enable study methods to be tailored to site-specific requirements. It is essential that the study objectives and methods are clear from the outset and are clearly documented in reports.

In reality, there will be a spectrum of scales of study, with more data needed for locations with considerable bird interest and where there are uncertainties as to likely impacts. Where raptors are the main concern, studies need to focus on raptor ranges rather than just on the proposed windfarm site to obtain contextual information on their use of the area. Thus, the study area may be zoned in terms of the intensity of the work. All studies need to take into account diurnal, tidal-cycle, weather-related and seasonal variations in site use, as appropriate. Study areas should comprise the proposed windfarm site plus buffer and at least one comparable reference, or control, area, matched as closely as possible to the windfarm site. Studies should adopt the Before-After Control-Impact (BACI) approach (e.g. Anderson *et al.* 1999).

The assessment of effects attributable to windfarms is complicated by the relatively large area potentially affected, the dispersed distribution of some of the species of concern (e.g. breeding waders and raptors, seabirds at sea) and the relative rarity of the events being measured (e.g. collision). Thus, the weight of evidence from numerous studies at different locations over extended periods of time will be needed to enable an informed judgement to be made about the impacts of windfarms. Cumulative impacts must be assessed.

All study methods have their limitations. It is important to understand the implications of the particular limitations associated with the methods used when interpreting the results.

The importance of early baseline studies to identify whether there are potential conflicts with nature conservation interests on a proposed windfarm site, cannot be over-stressed. Year-round studies are essential, over a minimum of one year but preferably for 2-3 years, to collect baseline data. This will enable an assessment to be made regarding the timing of importance of the site, if this is not known, but subsequent studies may concentrate on the key species of concern, at the appropriate time of year. Data covering more than one year will increase the reliability of the assessment by allowing for weather conditions and year-to-year variation in use. These preliminary studies will enable a risk assessment to be made of the potential impacts of the proposed windfarm and provide the baseline for subsequent comparison if the windfarm proceeds.

Sites with species of conservation concern will require studies before, during and post-construction on consented sites, using standard methods to monitor distribution and density over time, and behavioural studies (fixed point observations) to assess site use and collision risk/mortality. Suitable survey methods include transects or point counts, "look-see" size estimates of flocking species, e.g. winter coastal waterbirds (Reynolds *et al.* 1980, Brown & Shepherd 1993, Gilbert *et al.* 1998, Bibby *et al.* 2000). Fixed point observations (Morrison 1998, SNH 2002, Band *et al.* 2002) should be made from the minimum number of observation points to cover the windfarm area, together with a potentially larger area to reflect the scale of habitat use by the key species of interest (e.g. raptor territory ranges), and reference sites.

The sampling design should enable representative sampling of the windfarm area, plus buffer, and reference/control area(s) and ideally provide enough data points to permit statistical analysis (e.g. Pollock 1996). Sampling intensity may be increased at times of particular concern, e.g. waders or raptors during the breeding season, peak migration times, offshore post-breeding moulting flocks of seaducks. Longer-term monitoring, at least at a representative group of windfarms, is necessary to properly evaluate gradual or incremental change, especially in longer-lived bird species. It is also important to be able to distinguish short- and longer-term effects, hence the need to continue post-construction monitoring for several years (5-10 years or more). The duration and scale of monitoring will be dependent on periodic reviews against the monitoring targets. For example, some issues may require ongoing monitoring, subject to review, perhaps at a lower intensity in later years or in alternate years etc.

Most onshore studies of collision risk/mortality have involved a combination of observations of flight behaviour (visual and radar plus recording of calls) and corpse searches (see e.g. Anderson *et al.* 1997 & 1999, SNH 2002). Corpse searches need to be frequent and data require correction for scavenger removal, search effort and cause of death, otherwise they are prone to underestimation (see earlier sections of this report). Corpse searches are likely to be most useful where there are particular concerns about high collision risk and especially collision mortality of particular (large) species, but only if the results are calibrated. Mathematical collision risk models have been developed to assess collision risk (Tucker 1996a & b, Band *et al.* 2002), but such models can be tested only with appropriate input data and with an understanding of the determinants of site use, including measures of actual avoidance of fixed structures to incorporate in the models. Remote techniques have the potential to be more useful, but are still under development (see below). Risk assessments need to include consideration of poor weather, including the predicted frequency of such conditions on a site-by-site basis.

Offshore development of windfarms is in its infancy and efforts are being made to avoid the problems that have arisen with poorly sited windfarms on land. As well as important concentrations of seabirds, notably in the North and Baltic Seas, migratory flyways cross these areas. Denmark (Kahlert *et al.* 2000, Noer *et al.* 2000), Germany (BSH 2002, Projektgruppe OffshoreWEA 2001, Exo *et al.* 2002), and the Netherlands (Dutch government 2001) have established minimum requirements for environmental assessment and or pilot study sites. Similar approaches are being advocated in several other parts of Europe, including the UK; The DTI Technology Route Map[1] includes the need to identify key areas of concern and establish projects to quantify the effects, including international co-operation, as appropriate. In particular, recommendations are for Before-After Control-Impact (BACI) studies, as for onshore windfarm studies, comprising:

- determination of bird distribution and density, using transect surveys;
- detection of movements (including flight height) of local foraging birds and long-distance migrants, day and night, using a combination of visual observations, radar investigations and flight call recording (the latter to aid species identification from radar);
- studies of collision risk and mortality, for which infra-red video technology is being developed and tested (e.g. Kahlert *et al.* 2000, Desholm 2003), also pressure/vibration detectors on the turbine rotors have potential utility.

In view of the high level of variability in bird abundance at sea, a recommendation has been made for impact and reference areas to cover at least 200 km^2 each, although if proposed sites ≤50 km^2, a study area of 200 km^2 could comprise both impact and reference areas. In addition, the proposed windfarm site should be overlapped by a minimum 25% buffer zone all round (ICES 2002[2]).

Transect methods combined with spatially referenced recording using GPS, will be most appropriate, using aerial or ship-based surveys (NERI/website ref www.dmu.dk, Komdeur *et al.* 1992, Cranswick *et al.* 1998, Gilbert *et al.* 1998, Bibby *et al.* 2000, Noer *et al.* 2000), possibly including land-based surveys, depending on the distance offshore and extent of the study area. Aerial surveys have the advantage of enabling relatively rapid coverage of large sea areas. Ship-based surveys are generally better for species identification, behavioural observations and, presently there is more reference data from European Seabirds At Sea (ESAS), but they cover limited sea areas per unit time. Furthermore, there may be species and locational factors favouring one of these methods.

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[1] UK Department of Trade & Industry Research & Development programme for offshore wind energy.

[2] This draft report is subject to review by the relevant ICES Science Committees during the Annual Science Conference and Statutory Meeting, September 2003, and is cited here on that understanding.

Observations of flight behaviour pre- and post-construction are necessary for the assessment of collision risk and collision mortality. Radar is an important tool for this work, particularly to extend recording beyond the range of the human eye, to record nocturnal movements and movements during conditions of imperfect visibility, although supplementary methods are necessary for species identification (Cooper 1996 & 2000, Harmata *et al.* 2000a, Exo *et al.* 2002). Developments in the use of infra-red video cameras are likely to be useful offshore, for recording flight response close to turbines and collisions (Kahlert *et al.* 2000**,** Desholm 2003). The development of pressure/vibration sensors within the turbine blades is also a promising area of development for detecting collisions. These remote techniques, and image intensifiers may be usefully applied onshore too.

Appendix 2

COUNCIL OF EUROPE CONSEIL DE L'EUROPE

Convention on the Conservation
of European Wildlife and Natural Habitats

Standing Committee

Draft Recommendation No. … (2003) examined on … December 2003 on minimising adverse effects of wind power generation on birds

The Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats, acting under the terms of Article 14 of the Convention**,**

Having regard to the aims of the Convention to conserve wild fauna and its natural habitats; Recalling that Article 2 of the Convention requires Parties to take requisite measures to maintain the population of wild fauna at a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic requirements;

Recalling that Article 3.2 of the Convention requires each Contracting Party to undertake, in its planning and development policies and in its measures against pollution, to have regard to the conservation of wild fauna;

Recalling also the Convention on the Conservation of Migratory Species of Wild Animals (CMS) Resolution 7.5 on Wind Turbines and Migratory Species adopted by the 7th meeting of the Conference of the Parties (2002) and recognising the intention of the CMS to increase cooperation with the Bern Convention;

Recognising the environmental benefits of wind energy especially for addressing climate change, and the significance of reducing climate change for the long-term survival of Europe's wild birds;

Noting that windfarms, especially in marine areas, represent a relatively new technology for large-scale energy production the actual effects of which on nature and on different components of biodiversity cannot be fully assessed or predicted on the basis of the currently available information;

Concerned about the potential negative impacts of wind turbines and associated infrastructure on wild birds, as well as on their food sources and habitats, including:

(a) loss of, or damage to, habitat (including permanent or temporary feeding, resting, and breeding habitats);

(b) disturbance leading to displacement or exclusion, including barriers to movement

(c) collision mortality of birds in flight;

Recognising the need for a thorough environmental assessment procedure prior to selecting appropriate building sites and deciding on construction permits, in order to avoid damage to areas of particular ecological value;

Referring to the report *Windfarms and Birds: an analysis of the effects of windfarms on birds and guidance on environmental assessment criteria and site selection issues*, prepared by BirdLife International for the Council of Europe T-PVS/Inf (2003) 12;

Aware of the need for robust, objective baseline studies to inform sensitive siting to minimise deleterious effects on birds, other wildlife and their habitats, and the need for regular post-construction monitoring at consented installations where there are environmental sensitivities;

Recommends that Contracting Parties to the Convention:

1. take appropriate measures to minimise the adverse effects of wind turbines in birds, taking into account Resolution 7.5 of the Seventh Conference of the Parties of the Convention on the Conservation of Migratory Species of Wild Animals (Appendix 2) and applying those cautions to non-migratory bird species that might be affected by those turbines;
2. make use, as appropriate, of the guidelines set out in Appendix 1 to this recommendation, as summarised from the above referred report, on (A) criteria for environmental assessment; (B) precautions for site selection of windfarms; and (C) priorities for research to enable impacts of windfarms on birds to be minimized;
3. communicate to the Standing Committee the relevant steps which have been adopted or are envisaged concerning the implementation of this recommendation as well as information on the outcome of measures adopted, including a review of how the recommendation has helped their planning of wind energy developments;

Invites observer States to take note of this recommendation and implement it as appropriate.

Annex 1

Guidelines

Measures that may be considered as appropriate for minimising the negative impacts of wind power generation are listed for implementation by Contracting Parties. There is strong consensus that the location selected for windfarms is critically important to avoiding deleterious impacts on birds.

A. Criteria for Environmental Assessment

(i) National governments must undertake Strategic Environmental Assessment (SEA)[1] of all wind energy plans and programmes in their country. If there are potential trans-boundary effects, then international co-operation with other governments should be sought when undertaking the SEA. The scale of SEA should be determined by consideration of the likely biological scale of impacts as well as jurisdictional boundaries.

(ii) Specifically, these SEAs should include indicative mapping of bird populations, their habitats, flyways and migration routes (see B below) and an assessment of the plan's probable effects on these, to aid decision-making.

(iii) Thorough environmental assessment[2] should be undertaken for all windfarm developments that have the potential for damaging effects on wild birds or the wider environment, or in areas where there is uncertainty as to the potential effects. Environmental assessments of wind energy developments should include both:

   a. comprehensive environmental impact assessment for individual projects AND

   b. cumulative impact assessment of each windfarm proposal (including associated infrastructure onshore and offshore, such as new roads, powerlines and under-sea cabling) in conjunction with other projects (both other windfarms and other relevant projects).

(iv) The use of standard methods is essential to ensure comparability, adopting the Before-After Control-Impact (BACI) approach with consistent application of these methods before, during and after construction in the windfarm area and a reference area for comparison.

(v) A minimum one-year baseline field study should be undertaken to determine the use of the study-area by birds.

(vi) Post-construction monitoring needs to enable short- and long-term effects and impacts to be distinguished and satisfactorily addressed.

(vii) There is a need for best practice guidance on standard study methods, to inform the EIA process.

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[1] For example, as set out in Directive 85/337/EC of the European Parliament and of the Council '*on the assessment of the effects of certain plans and programmes on the environment' (*SEA Directive).

[2] For example, as set out in Directive 2001/42/EC of the European Parliament and of the Council '*Assessment of certain public and private projects on the environment'* (EIA Directive) as amended by Directive 97/11/EC.

The following species are indicative of those that should tend to be focal species for environmental assessments where they are at risk as they are considered to be particularly sensitive, or potentially so, to windfarms (disturbance displacement, barriers to movement, collision, habitat loss or damage), although in many cases there is a lack of impact studies to date. Focal species are likely to be site and issue specific and may change in the light of further research or change in conservation status.

Species group (eg species)	**Disturbance displacement**	**Barrier to movement**	**Collision**	**Direct habitat loss/damage**
Gaviidae, divers (red-throated diver *Gavia stellata*)	√	√	√	
Podicipedidae grebes	√			
Sulidae gannets & boobies			√	
Phalacrocoracidae (shag *Phalacrocorax aristotelis*)				√
Ciconiiformes herons & storks			√	
Anserini, swans (whooper swan *Cygnus cygnus*) and geese (pink-footed goose *Anser brachyrhynchus*, European white-fronted goose *A. albifrons*, barnacle goose *Branta leucopsis*, brent goose *B. bernicla*)	√		√	
Anatinae, ducks (eider *Somateria mollissima*, long-tailed duck *Clangula hyemelis*, common scoter *Melanitta nigra*)	√	√	√	√
Accipitridae raptors (red kite *Milvus milvus*, white-tailed sea eagle *Haliaeetus albicilla*, lammergeier *Gypaetus barbatus*, griffon vulture *Gyps fulvus*, imperial eagle *Aquila heliaca*, golden eagle *A. chrysaetos*, Bonelli's eagle *Hieraetus fasciatus*)	√		√	
Charadriiformes waders (European golden plover *Pluvialis apricaria*, black-tailed godwit *Limosa limosa*, Eurasian curlew *Numenius arquata*)	√	√		
Sternidae terns			√	
Alcidae alcids/auks (guillemot *Uria aalge*)	√		√	√
Strigiformes owls			√	
Tetraonidae (black grouse *Tetrao tetrix*, capercaillie *T. urogallus*)	√		√	√
Gruidae cranes	√	√	√	
Otididae bustards	√		√	√
Passeriformes especially nocturnal migrants			√	

B. Precautions for site selection of windfarms

There is strong consensus that the location selected for windfarms is critically important to avoiding deleterious impacts on birds.

There should be precautionary avoidance of locating windfarms in designated or qualifying sites for nature conservation, including Important Bird Areas (IBAs), or other areas with large concentrations of birds, such as migration crossing points, or

(a) species identified as being of conservation concern. The favourable conservation status of habitats and species in these areas is a central tenet to their designation, requiring demonstration of compatibility with this aim by any proposed development.

(b) As part of effective regional planning, there is a need to identify species and areas of concern, to map potential and no-go locations for wind energy development based on nature conservation concerns, for example avoidance of migratory corridors and other large concentrations of birds. This may require the collection of additional information, especially offshore.

(c) There is a need for statutory marine protected areas to be identified and designated.

C. Priorities for research to enable impacts of windfarms on birds to be minimised

(a) Research and monitoring should be implemented by national governments and the wind energy industry, in consultation with relevant experts, to improve our understanding of the impacts of windfarms. This will be an iterative process that will inform decision-making, appropriate site selection and windfarm design. The results of research should be published in international scientific journals, including a summary, preferably in English, to ensure wider dissemination.

(b) Research and monitoring requirements should encompass the following:
  i effects and potential population level impacts on birds of disturbance displacement, barriers to movement, collision mortality and habitat loss or damage;
  ii effectiveness of different windfarm layouts and turbine design to provide mitigation.

(c) There need to be incentives to ongoing technological development to maximise efficiency of windfarms and to reduce dependency on the limited shallow water habitats offshore.

A useful subject for further study is to look in detail at individual case studies to evaluate examples of conflict resolution, case law, or trends in casework throughout the Council of Europe area.

Annex 2

UNEP

Convention on the Conservation of Migratory Species of Wild Animals

CMS

RESOLUTION 7.5*

WIND TURBINES AND MIGRATORY SPECIES

Adopted by the Conference of the Parties at its Seventh Meeting (Bonn, 18-24 September 2002)

Recalling that Article II of the Convention acknowledges the need to take action to avoid any migratory species becoming endangered;

Recalling also the need to preserve wildlife in the marine environment as stipulated in the relevant legislation of the European Community and in the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), the Helsinki Convention on the Protection of the Baltic Sea Area, the Bern Convention on the Conservation of European Wildlife and Natural Habitats, and the Bergen Declaration of the Fifth International Conference on the Protection of the North Sea;

Acknowledging Article VII of the Convention whereby the Conference of the Parties may make recommendations to the Parties for improving the effectiveness of this Convention;

Considering that the Strategic Plan for 2000 - 2005 adopted by Resolution 6.4 requires Parties to review the special problems faced by migratory animals in relation to various obstacles to migration and to propose remedial measures that may have widespread applicability;

Recognising that Resolution 4.5 directs the Scientific Council *inter alia* to recommend solutions to the Conference of the Parties to problems relating to the scientific aspects of the implementation of the Convention in particular with regard to the habitats of migratory species;

Recognising the environmental benefits of wind energy especially for addressing climate change, and the significance of reducing climate change for the long-term survival of migratory species;

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[*] The original draft of this resolution, considered by the Conference of the Parties, was numbered 7.13.

Noting that wind turbines especially in marine areas represent a new technique of large scale energy production, the actual effects of which on nature and on different components of biodiversity cannot be fully assessed or predicted at present;

Recognising the lack of sufficient and relevant research on such effects, especially on nature, and the lack of data on the distribution and migration of species concerned;

Concerned about the possible negative impacts of wind turbines on migratory species of mammals and birds, as well as on their food sources and habitats *e.g.*:

(a) destruction or disturbance of permanent or temporary feeding, resting, and breeding habitats;

(b) increased collision risk for birds in flight;

(c) through electric and magnetic fields of connecting power cables; or

(d) emission of noise and vibrations into the water;

Recognising the need for a thorough environmental impact assessment prior to selecting appropriate building sites and issuing construction permits, in order to avoid areas of particular ecological value and habitats with high nature conservation needs;

Aware of the need to regularly monitor and assess the actual impacts of wind turbines by exchange of international experience and site-specific effect monitoring programmes in existing wind turbine plants; and

Noting especially the potential risk that several hundred of such marine installations with heights up to 150 metres may present as obstacles in flyways, and wishing to minimise possible adverse effects on nature;

The Conference of the Parties to the
Convention on the Conservation of Migratory Species of Wild Animals

1. *Calls* upon the Parties:

   (a) to identify areas where migratory species are vulnerable to wind turbines and where wind turbines should be evaluated to protect migratory species;

   (b) to apply and strengthen, where major developments of wind turbines are planned, comprehensive strategic environmental impact assessment procedures to identify appropriate construction sites;

   (c) to evaluate the possible negative ecological impacts of wind turbines on nature, particularly migratory species, prior to deciding upon permission for wind turbines;

(d) to assess the cumulative environmental impacts of installed wind turbines on migratory species;

(e) to take full account of the precautionary principle in the development of wind turbine plants, and to develop wind energy parks taking account of environmental impact data and monitoring information as it emerges and taking account of exchange of information provided through the spatial planning processes;

2. *Instructs* the Scientific Council to assess existing and potential threats from offshore wind turbines in relation to migratory mammals and birds, including their habitats and food sources, to develop specific guidelines for the establishment of such plants and to report to the Conference of the Parties accordingly at its next meeting; and

3. *Invites* relevant intergovernmental organisations as well as the European Community and the private sector to cooperate with CMS in efforts to minimise possible negative impacts of offshore wind turbines on migratory species.

* * * * *

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