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CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE
AND NATURAL HABITATS

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Windfarms and Birds :
An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues

Report written by BirdLife
On behalf of the Bern Convention
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Secretariat Memorandum
prepared by
the Directorate of Culture and of Cultural and Natural Heritage

Executive Summary

This report was commissioned by the Council of Europe for the Bern Convention. Its remit was to '*analyse the impact of wind farms on birds, establishing criteria for their environmental impact assessment and developing guidelines on precautions to be taken when selecting sites for wind farms*'.

The Impact of Wind Farms on Birds

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

- Disturbance leading to displacement, including barriers to movement
- Collision mortality
- Direct loss of habitat to wind turbines and associated infrastructure

Disturbance

The effects attributable to wind farms 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 to the birds. The scale of such habitat loss, together with the availability of other suitable habitats that can accommodate displaced birds, will influence the impact. There are several reliable studies indicating negative effects up to 600m 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*). Disturbance potentially may arise from increased human activity in the vicinity of the wind farms, e.g. maintenance visits, facilitation of access via access roads, presence/noise of turbines. Few studies are conclusive in their findings, often because of a lack of well-designed studies both before and after construction of the wind farm.

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. The cumulative effects of large wind farm installations may be considerable if bird movements are displaced as a consequence. This may lead to disruption of ecological links between feeding, breeding and roosting areas. Wind farm 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, again indicating a variable response that is both site- and species-specific. The proposals for large wind farms in shallow sea areas may conflict with the feeding distributions of seabirds, notably seaducks if these are displaced as a result of disturbance.

Collision Risk and Mortality

The majority of studies have so far demonstrated very low collision mortality *rates* attributable to wind farms. However, this does not necessarily mean that collision mortality is insignificant, particularly at large, poorly sited wind farms in areas where large concentrations of birds (including IBAs), especially migrants, large raptors or other large soaring species, are present, e.g. Altamont Pass in California, USA, and Tarifa in Spain. In these cases actual deaths resulting from collision are high, notably of golden eagle *Aquila chrysaetos*, griffon vulture *Gyps fulvus*, respectively. 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. Wind speed, flight type and height all influence the risk of collision, as do species, age and stage of the bird's annual cycle. Most studies have been of small turbines; the implications of newer, larger turbines may be different, but it is too early to tell. The importance of wind farm location and layout in determining the risk of collision by birds with wind turbines is apparent from studies both onshore and offshore. Thus, site selection is crucial to minimising collision mortality. It is therefore very important that alternative locations are proposed for the potentially most hazardous wind farms.

Assessment of bird collision risk and mortality, arising from collision or electrocution, needs to include both wind turbines and the power lines associated with energy transport from the wind farm.

Direct Loss of Habitat

Direct loss of habitat, as a result of the construction of wind farms, is at present not generally perceived to be a major concern for birds, depending on local circumstances and the scale of land-take required for the wind farm and associated infrastructure. Offshore, direct habitat loss is generally small-scale, primarily for turbine bases and cables at sea. However, increasingly large wind farms, especially on feeding areas such as sandbanks in shallow waters, may give cause for concern and habitat change or damage may be an issue. 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 be dependent on the size of the wind farm and especially the extent of any road network required. Cumulative habitat loss may be an issue both onshore and offshore.

Other Issues

Use of wind turbines as platforms for roosting and nesting is not seen as a significant problem. However, research needs to be undertaken to clarify the extent of bird use. In terms of hydrological and geomorphological effects of wind farms, there is more likely to be a problem with larger scale wind farms where sensitive soil hydrology or marine sedimentary processes may be disrupted. In the offshore environment, there also 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.

Environmental Assessment and Site Selection Guidelines

Criteria for Environmental Assessment

All wind farm 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, need a thorough environmental assessment. This needs to include comprehensive environmental impact assessment for individual projects and cumulative impact assessment of each wind farm proposal (including associated infrastructure onshore and offshore, such as new roads, power lines and under-sea cabling) in conjunction with other projects (both other wind farms and other relevant projects). The use of standard methods is essential to ensure comparability, adopting the Before-After Control-Impact (BACI) approach. It is recommended that a <u>minimum</u> one-year baseline field study should be undertaken to determine the use of the study-area by birds. Post-construction monitoring needs to enable short- and long-term effects and impacts to be distinguished and satisfactorily addressed.

On the basis of the literature review and more than 10 years experience by the BirdLife partners, the following species groups and example species are considered to be particularly sensitive, or potentially so, to wind farms (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 environmental assessment[1]:

Species group (e.g. species)	**Disturbance displacement**	**Barrier to movement**	**Collision**	**Direct habitat loss/damage**
Gaviidae, divers (red-throated diver *Gavia stellata*, black-throated diver *G. arctica*)	v	v	v	
Podicipedidae grebes (red-necked grebe *Podiceps grisegena, Slavonian grebe P. auritus)*	v			
Sulidae gannets & boobies			v	
Phalacrocoracidae (shag *Phalacrocorax aristotelis*)				v
Ciconiiformes herons & storks			v	
Anserini, swans (whooper swan *Cygnus cygnus*) and geese (pink-footed goose *Anser brachyrhynchus*,	v		v	

[1] It should be noted that this table is indicative only, and reflects available evidence at the time of writing.

European white-fronted goose *A. albifrons*, barnacle goose *Branta leucopsis*, brent goose *B. bernicla*)				
Mergini seaducks (eider *Somateria mollissima*, long-tailed duck *Clangula hyemelis*, common scoter *Melanitta nigra*)	v	v	v	v
Accipitridae raptors (honey buzzard *Pernis apivorus*, white-tailed sea eagle *Haliaeetus albicilla*, lammergeier *Gypaetus barbatus*, gryffon vulture *Gyps fulvus*, marsh harrier *Circus aeruginosus*, hen harrier *C. cyaneus*, Montagu's harrier *C. pygargus*, imperial eagle *Aquila heliaca*, golden eagle *A. chrysaetos*, Bonnelli's eagle *Hieraetus fasciatus*)	v		v	
Charadriiformes waders (Eurasian curlew *Numenius arquata*)	v	v		
Sternidae terns			v	
Alcidae alcids/auks (guillemot *Uria aalge*)	v		v	v
Tetraonidae (black grouse *Tetrao tetrix*, capercaillie *T. urogallus*)	v		v	v
Gruidae cranes			v	
Otididae bustards	v		v	v

Precautions for Site Selection of Wind Farms

Wind farm development should not have an adverse effect on designated sites for nature conservation or areas likely to be designated as such in the future, including Important Bird Areas (IBAs). 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. There should be precautionary avoidance of siting wind farms in such areas.

Recommendations

There is a 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 wind farms. This will be an iterative process that will inform decision-making, appropriate site selection and wind farm 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 wind farm layout and turbine design to provide mitigation.

National governments must undertake Strategic Environmental Assessment (SEA)[2] 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.

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.

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

[2] 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*'.

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.

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

Autecology	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 wind farm, 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 wind farm (Anderson et al. 1999).
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 set designated under Directives 79/409/EEC and 92/43/EEC.
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 wind farm proposal, but otherwise is highly comparable to the proposed wind farm site, provides a comparison with studies on the wind farm 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 which is protected by either national or international law.

CONTENTS

1. INTRODUCTION

1.1 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 arising from climate change, arising from over-reliance on fossil fuels. Of the most advanced renewable technologies, wind energy generation is set to make a substantial contribution to energy generation in the countries to which the Bern Convention applies. By the end of 2001, 4,500 MW of wind power capacity was added to the European electricity grids, bringing the installed capacity from wind in Europe to more than 17,000 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 wind farms are likely to make up a significant part of future wind farm development in Europe. The assessment of potential environmental impacts, notably on biodiversity and habitats, should be an integral part of the planning process.

1.2 This report first presents a review of the literature (published and unpublished) that documents the findings of research into bird - wind farm interactions at both onshore and offshore wind farms, together with recommendations derived from those studies. This includes issues of:

- Disturbance leading to displacement
- Collision mortality
- Direct loss of habitat to wind turbines and associated infrastructure; and
- Other potential effects.

1.3 The report then gives guidance on:

- Criteria for assessing environmental impacts of wind farms on birds; and
- Precautions to be taken when selecting sites for wind farms.

1.4 This guidance is the result of more than 10 years of experience from BirdLife International and its European Partners, regarding the compatibility of wind farms with bird populations and habitats, and has taken into account the literature that documents the findings of research into bird - wind farm interactions at both onshore and offshore wind farms, together with recommendations derived from those studies.

2. REVIEW OF THE LITERATURE ON THE IMPACTS OF WIND FARMS ON BIRDS

2.1 The purpose of this section of the report is to provide an updated summary of the literature relating to impacts of wind farms 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 wind farms) to information included in these earlier recommended reviews:

- Crockford, N.J. (1992) *A review of the possible impacts of wind farms 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 wind farms and other aerial structures upon birds.* Scottish Natural Heritage Review No. 21.
- SGS Environment (1996) *A review of the impacts of wind farms on birds in the UK.* ETSU W/13/00426/REP/3.

2.2 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 2002, from principally English language documentation.

2.3 The emphasis of this review is studies of bird – wind farm interactions. The literature indicates that the main potential hazards to birds from wind farms are:

- Disturbance leading to displacement, including barriers to movement.
- Collision mortality.
- Loss of habitat to wind turbines and associated infrastructure.

2A. Disturbance

Disturbance Onshore

Summary

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

2.5 The effects attributable to wind farms 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 to the birds. The scale of such habitat loss, together with the availability of other suitable habitats that can accommodate displaced birds, will influence the impact. There are several reliable studies indicating negative effects up to 600m 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*)). Disturbance potentially may arise from increased human activity in the vicinity of the wind farms, e.g. maintenance visits, facilitation of access via access roads, presence/noise of turbines. Few studies are conclusive in their findings, often because of a lack of well-designed studies both before and after construction of the wind farm.

Breeding Birds

2.6 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, whereas shorter-lived species with a more rapid turnover of individuals or species that are less site-faithful may display different responses to change, so caution is advised in interpreting these results.

2.7 At Burgar Hill, on Orkney, Scotland, again studies of distance effects in relation to the 3-turbine wind cluster, found no significant difference in numbers of breeding pairs of ducks (*Anatinae*), 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 cumulative assessment of several similar studies will provide a measure of the consistency of the response.

2.8 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 wind farm area, and higher densities in the reference areas than within 80m of the wind turbines. They did not find an effect of operational versus non-operational turbines.

2.9 At Windy Standard wind farm 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 *(Alauda arvensis)* and red grouse *(Lagopus lagopus scoticus)* and no demonstrable effects were detected on these species (DH Ecological Consultancy 2000b).

2.10Thomas (1999) undertook a study of 10 upland wind farms in the UK, comparing breeding bird distributions (Moorland Bird Survey method, Brown & Shepherd 1993) at wind farm sites with their respective reference sites, and in relation to Phase 1 habitat data. 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. Whilst the study acknowledges some shortcomings, (such as only one survey visit to each site and differences between some reference sites and the wind farm site in terms of habitat composition), there were some useful findings:

- Overall bird densities at wind farm sites were not significantly lower than on reference sites.
- There were no significant differences between densities on wind farm sites and reference sites for common skylark or meadow pipit, the only species sufficiently numerous to enable statistical comparison, although there were
- There was no evidence of clumped distributions of breeding birds and no significant difference in the extent of clustering between wind farm sites and reference sites, i.e. the spatial distribution of breeding birds was comparable both between and within wind farm sites and reference sites.
- Taller wind turbines, longer rotor blades (although limited variation in blade lengths studied), and larger wind farms 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. Avoidance of wind turbines from combined species data was observed at only one of the ten study sites.

Feeding and Roosting Birds

2.11 In The Netherlands, variable levels of disturbance have been apparent for feeding and roosting birds (Spaans et al. 1998). At Oosterbierum, (Winkelman 1992a) found significantly smaller numbers of feeding and roosting birds within the wind farm and surrounding area when the turbines were operational, with effects observed up to 500m 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),* 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 wind farm from any other contemporary changes in the absence of a reference area, which limits the usefulness of this study.

2.12 Studies at Urk, The Netherlands (Winkelman 1989) found decreases within the wind farm area in winter, which extended to 300m away from the wind farm, for mallard, tufted duck, common pochard (*Aythya ferina*) and common goldeneye (*Bucephala clangula*), but little or no effect on great-crested grebe (*Podiceps cristatus*), Eurasian coot, common gull, or gulls combined (*Laridae*), and increased numbers of black-headed gull and greater scaup (*Aythya marila*) in the wind farm area. Most results for swans and geese were inconclusive, except for whooper swan 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, as a result of disturbance displacement due to turbines (Larsen & Clausen 1998, Clausen et al. 1999).

2.13 Avoidance behaviour by pink-footed geese 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 wind farm layout and indicated a cumulative effect of additional wind farms in reducing the habitat available to feeding *geese*. The avoidance distance in response to wind farm layouts in lines and in clusters were ca 100m and ca 200m 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.

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

2.15 Blyth Harbour wind farm, in the UK, is sited in a commercial harbour in an industrial area , and comprises nine turbines (300kW) built at 200m intervals along the estuary's breakwater (Still et al. 1996). The breakwater is a Site of Special Scientific Interest [3] because it hosts a large winter roost of purple sandpipers *(Calidris maritima),* and the estuary it protects adjoins a Special Protection Area [4] and Ramsar site [5]. The estuary supports a relatively high density of birds. During peak periods, up to ca 5,000 bird movements a day occur adjacent to the wind farm. Counts of all bird species we re undertaken before construction (Dec. 1991-July 1992), during construction (Aug 1992 -Jan 1993) and the early phase of operation (Jan 1993 -July 1995). Great cormorants *(Phalacrocorax carbo*) were temporarily displaced from their roost during construction, but returned once the wind farm 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) rema ined comparable after construction.

2.16 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 win d farms in Important Bird Areas (IBAs) [6], on the basis of the risk of disturbance, indicated by studies such as those above, leading to avoidance of turbines by staging geese, (Elbe, on appeal in 2000, & Leibugt).

Disturbance Offshore

Summary

2.17 This sect ion considers the effects of offshore wind farms on birds.

2.18 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. The proposals for large wind farms in shallow sea areas may conflict with the feeding distributions of seabirds, notably for seaducks, if these are displa ced as a result of disturbance.

2.19 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 wind farm, spacing of turbines, the extent of displacement of flying birds and their ability to compensate for increased energy expenditure. The cumulative effects of large wind farm installations may be considerable if bird movements are displaced as a consequence. This may lead to disruption of ecological links between feeding, breeding and roosting areas. Wind farm 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 .

2.20 The first offshore wind farm was built in 1990, 250m off the coast at Nogersund in Sweden (Larsson 1994). In view of the large numbe rs 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 50m. 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.

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3 As designated under the UK Wildlife and Countryside Act 1981.
4 As designated under the Directive on the Conservation of Wild Birds (79/409).
5 As designated under the Convention on Wetlands of Internat ional Importance especially as Waterfowl Habitat (Ramsar, Iran 1971), as amended by protocol of 1982.
6 As identified by Birdlife International in their European IBA programme -Heath & Evans (2000).

2.21 Guillemette et al. 1998 found decreases in the numbers of common eider and common scoter (*Melanitta nigra)* in late winter, in the wind farm area compared with the reference area, in the two years following construction of the wind farm 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 wind farm 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 (Guillemette et al. 1999). Unfortunately, no studies were continued in the Ringebjerg Sand reference area in the third post-construction year.

2.22 The studies at TunØ Knob were fairly comprehensive, compared with many other wind farm 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 wind farm), although the authors themselves point out various limitations to the work:

- No collection of data 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 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 inconclusive.
- 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 wind farm, comprising 10 small turbines and so the results may not have wider applicability to larger wind clusters or larger turbines.

2.23 Most common eiders and common scoters were observed =10km from the coast during the 2.5 years of baseline surveys for the proposed wind farm at Horns Rev, Denmark (Noer et al. 2000, Christensen et al. 2001, 2002), and were closely associated with shallow waters =6m 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 wind farm 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 wind farm plus 4km buffer, would 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 wind farm was completed in summer 2002 (www.hornsrev.dk/Engelsk/nyheder/nyh_sep_02/UK-sept_02.htm#Erection), and will be the subject of detailed post-construction monitoring which will determine whether there are impacts on birds attributable to the wind farm). This wind farm of ca 80 turbines (150MW) is located 14km offshore, in waters 6.5-13.5m deep.

2B. Collision Risk and Mortality

Collision Risk & Mortality Onshore

Summary

2.24 This section considers collision risk from onshore, including coastal, wind farms. 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.

2.25 The majority of studies have so far demonstrated very low collision mortality rates attributable to wind farms. However, this does not necessarily mean that collision mortality is insignificant, particularly at large, poorly sited wind farms in areas where large concentrations of birds (including IBAs), especially migrants, large raptors or other large soaring species, are present, e.g. Altamont Pass in California, USA, and Tarifa in Spain. In these cases actual deaths resulting from collision are high, notably of golden eagle (*Aquila chrysaetos*), griffon vulture (*Gyps fulvus*), respectively. Even relatively small increases in mortality rates may be significant for populations of some species, especially large, long-lived species with generally low annual productivity and slow maturity, notably so when already rare. Wind speed, flight type and height all influence the risk of collision, as do species, age and stage of the bird's annual cycle.

2.26 Most studies have been of small turbines; the implications of newer, larger turbines may be different, but it is too early to tell. The importance of wind farm location and layout in determining the risk of collision by birds with wind turbines is apparent from the literature. Thus, *site selection* is crucial to minimising collision mortality. It is very important that alternative locations are proposed for the potentially most hazardous wind farms. Assessment of bird collision risk and mortality, arising from collision or electrocution, needs to include both wind turbines and the power lines associated with energy transport from the wind farm**.**

Behavioural Observations

2.27 Actual observations of collisions are relatively rare and so often not recorded during studies. Remote techniques tend to be better for measuring such events and research is underway to develop automated recording systems, notably 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 pers. Comm.).

2.28 The experimental wind farm, at Oosterbierum in The Netherlands, was the subject of studies between 1984 and 1991. The study area comprised 18, 300kW, wind turbines, together with meteorological towers and control buildings. Studies of birds' responses at night to turbines at the Oosterbierum windpark, 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.

2.29 Observations in daylight within 200-300m of turbines indicated that over 75% of all reactions took place within 100m, ducks reacting at the greatest distance and small passerines reacting closest to the wind turbines. Habituation was indicated for local birds which 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 0-50m 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 50m) 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 wind farm (Winkelman 1992c), which could increase the risk of collision.

2.30 During 1994-98, nocturnal studies of flight paths and altitudes were undertaken at several locations near tidal areas of the Delta and Wadden Sea in The Netherlands (van der Winden et al. 1999). The studies combined the use of vertical and horizontal marine surveillance radar plus observations and recording of calls. Waders may use different roosts by day and night. The study recorded substantial movements between mudflats and high tide roosts, several 1000 movements per hour. The average altitude was <100m, mostly <75m, so potentially within the height zone occupied by a rotating turbine blade, with Eurasian oystercatcher recorded at the lowest and grey plover (*Pluvialis squatarola*), Eurasian curlew, dunlin (*Calidris alpina*) and bar-tailed godwit (*Limosa lapponica*) at the highest altitudes recorded. On average, flight was higher with tailwinds than with headwinds.

2.31 Radar studies of nocturnal movements of diving ducks between feeding and roosting areas on the Ijsselmeer, in the Netherlands indicated that most flew below 75m, flight height being lower in inclement conditions such as strong headwinds (Dirksen et al. 1998a & b, Spaans et al. 1998). Tufted duck and common pochard movements took place predominantly during darkness and so these species were considered to be the most at risk of collision, whereas those of greater scaup occurred mainly at dusk and dawn. During moonlit nights, tufted duck and common pochard flew between the 4 turbines, whereas on moonless nights more birds flew parallel to the line of turbines i.e. around rather than through the line of turbines, indicating that local wintering birds may habituate to the presence of wind turbines (Spaans et al. 1998). However, this study provides further 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 wind farms 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 wind farm 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.

2.32 Observed flight reactions to wind turbines in Schleswig-Holstein indicated that waders, terns and wildfowl reacted 200-500m from the turbines, whereas gulls reacted at 100-150m 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 brent geese (*Branta leucopsis*). Observations such as these are most useful when combined with similar observations from other wind farms, using standard methods and combined with supplementary information on weather conditions, wind speed and direction, and the birds, e.g. purpose of flight.

2.33 Studies of the behavioural response by common terns (*Sterna hirundo*) to power lines, 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 power lines, 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.

2.34 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. Nonetheless, herring and great black-backed gulls did suffer mortalities (a minimum of seven herring gulls and seven great black-backed gulls 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 (<15m). 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.

2.35 Observations of daytime flight behaviour of gulls, mainly herring and lesser black -backed (*Larus fuscus*), and common terns, at two wind farms near Rotterdam, also found that birds flew between the turbines to and from their breeding colonies and marine feeding areas (van den Bergh et al. 2002).

2.36 There are particular concerns about the implications of wind farms 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 (in PNAWPPM -III 2000) provides a useful summary, albeit simplified, from which the following points can be drawn:

- Most landbirds fly at night, especially in the early part from soon after sunset.
- Most birds of prey migrate during the day.
- Most waterbirds migrate during day and night; many shorebirds depart in late afternoon (e.g. Gudmundsson 1993, Tulp et al. 1994).
- Migrants prefer tail winds or only light headwinds (also Bruderer 1980).
- Most nocturnal migration by passerines is at high altitude, well above turbine height.
- The risk for migrants is principally during take-off and descent or as a result of light-attraction especially in conditions of poor visibility, or when strong headwinds or poor visibility force them to fly at lower altitude. Flight height is also reduced over ridges.
- It has been demonstrated that diurnal migrants are often concentrated along linear features such as coastlines or valleys, but do sometimes cross mountain ranges.
- As study methods for nocturnal migration are refined, more examples of similar behaviour at night, to that observed by day, are apparent.
- Migration stopovers may bring more migrants into wind turbine height zones during ascent and landfall, especially species which lose or gain height gradually e.g. swans.
- Most long-distance migration sea-crossings are on a broad front, although there are narrow sea passages at which migrants concentrate, notably Gibraltar, the Bosporus and Falsterbo.

2.37 There is a lack of information about migratory routes, especially nocturnal ones around the coast and about any concentrations at critical heights which would increase the risk of collision. Flight altitude depends on species, weather, wind speed and direction, time of day and topography (Alerstam 1990). Winkelman's studies (1992b, 1995) of wind farms in The Netherlands suggested that most diurnal migration and local movements were below 10m, whilst nocturnal migrations, especially in autumn were up to 50m or more, i.e. at the height of the turbine blades, in the vicinity of coastal wind farms. 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.

2.38 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 =25m. Most diurnal movement was at low altitude. This research into bird flight behaviour aids the interpretation of observations made in relation to wind farms. Winkelman (1992b) observed large-scale autumn migration at Oosterbierum, The Netherlands, notably into headwinds, to be at the height of the turbine blades, although with tail winds birds often flew higher, above the turbines.

2.39 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 altit ude, along the valley. Raptors, mainly golden eagles, commonly moved through the site, but apparently without problem; no collisions were recorded with the wind turbine. The few collision fatalities (6 in winter, all grouse (*Tetraonidae*) species) recorded by the study were associated with a control tower of lattice construction with guy wires.

2.40 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 power lines (Butler 1999) and wind turbines.

2.41 Most passerines migrate at1000-1500m (Alerstam 1990), whilst migrating waterfowl tend to fly at greater heights. Waders leaving Mauretania on their northward migration in sp ring 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). Ho wever, migration flight height is dependent on many factors, such as flight distance, windspeed, air temperature and humidity, as well as the size and structure of the bird. For example, in fog birds may be grounded or fly at lower altitude, and may becom e disorientated.

2.42 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. 2000). Daytime visual observations were used to verify species identification, although there may have been some different species by day and by night. Autumn migration was more protracted than vernal migration, a feature recognised in other migration studies. The highest passage rates were recorded within 4 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). 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 wind farm developments, as indicated above.

2.43 At Klickitat County pro posed wind farm development in Washington State, USA, pre - construction Before-After Control Impact (BACI) studies were initiated (Erickson et al. 1999). Of the nearly 10,000 birds of 73 species observed during the first year, only 13% of flights were reco rded within the likely rotor swept area, but over 40% of raptor movements were within the height category that would maximise their collision risk.

2.44 Winkelman (1992c) considered that wind farm 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.

2.45 Tarifa is a major migration corridor and has the greatest potential for wind energy generation in Spain (Janss in PNAWPPM -III 2000). The early wind far ms 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/BirdLife 1995).

2.46 Studies in the Strait of Gibraltar, Andalus ia, in Spain, concentrated on breeding and migratory soaring birds at two wind farms, together comprising 256 turbines (SEO/BirdLife 1995). Flight behaviour within 250m of turbines was studied to enable a collision risk assessment. Wind speed, flight typ e and height all influence the risk of collision. At Pesur, soaring flights at low wind speeds (=8ms^{-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. However, only low numbers of migration flights were observed close to the turbines. A single group of 28 wind turbines was responsible for 57 % of griffon vulture mortality. SEO/BirdLife [7] advocated operation of these turbines only at wind speeds in excess of $8.5ms^{-1}$, but this corrective measure was not implemented by the companies.

2.47 Consequently, a series of post-construction surveys have been implemented, including that by Janss (in PNAWPPM-III 2000) of an installation of 66 turbines on top of a mountain ridge. The study covered the wind farm 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 wind farm area. The main findings were as follows:

- Migrants passed over the wind farm at higher average altitude (>100m) than over the reference areas (ca. 60m).
- 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 wind farm or reference sites and no relationship between flight altitude and wind speed.
- Birds changed flight direction more often when crossing the wind farm than elsewhere.

2.48 The extent to which the differences between the wind farm and the reference areas are attributable to the wind farm remains uncertain owing to the absence of pre-construction data.

2.49 Spanish experience indicates a detrimental impact of wind farms 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) advocate that wind farms should not be located in critical areas for the species (including juvenile dispersion areas). 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

2.50 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 wind farms (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. 1998).

2.51 Winkelman (1992b) recognised that estimates of collision mortalities were likely to be underestimates, 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 (1992a) and 73% (60-83%, n=22) at Urk (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).

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[7] Sociedad Espanola de Ornitologia.

2.52 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 carcases, 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 carcases over 7 days (Osborn et al. 2000). The small number of carcases found during the 20 month study period indicated 0.33-0.66 fatalities per turbine per year, and an increased risk of collision when more birds were present. These and Winkelman's studies 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.

2.53 At Blyth, in the UK (Still et al. 1996) carcase 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 power lines. Over the 2.5 -year operational period, 31 wind farm collision victims (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 wind farm. 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. Analysis of carcases showed that collisions attributable to the wind farm were comparable with other causes of mortality, although for common eider, herring and great black-backed gulls mortality associated with the wind turbines was considerably higher than the background mortality (pre-construction mortality, in the absence of a wind farm). 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 carcases), 12% were collision victims, 20% due to starvation, 15% from fishing line entanglement, 14% from oil conta mination 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 li mitations of corpse searches for assessing collision mortality.

2.54 In Belgium, comparison of collision mortality, based on corpse searches, at three wind farms identified herring gull, lesser black -backed and black-headed gulls as the main casualties; th ese were also the most numerous species present. However, common terns, little terns (*S. albifrons*), kittiwake (*Rissa tridactyla*) and raptors (kestrel, sparrowhawk (*Accipiter nisus*) and peregrine (*Falco peregrinus*) were also among the casualties (Everaert et al. 2002).

2.55 At Kreekrak, in the Netherlands, studies of collision mortality associated with a coastal wind farm, comprising 5 turbines, were instigated preparatory to possible expansion of the wind farm (Musters et al. 1995, 1996). Corpse searches on alternate days took place over one year and cause of death was established where possible. Monthly experimental 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 recovery during the year. Predictions of mortality were made for a 20 -turbine wind farm 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. This study too highlights the problem associated with assessing collision mortality offshore, where remote technologies are likely to be most valuable.

2.56 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 locatio ns with vulnerable species or migratory concentrations. Studies in Andalusia, Spain (SEO/BirdLife1995), combined searches for corpses and injured birds, twice-weekly around a random sample of 87 of the turbines and weekly beneath powerlines, during the year 15 Dec 1993 to 15 Dec 1994. Several experiments were implemented during this time to assess predation losses. Including corrections for predation removal (which could be applied only to common kestrels in view of the otherwise small sample sizes), there were estimated to be 106 collision victims (97 due to turbines, 9 due to power lines), mostly of medium to large birds. Common kestrels (49) and griffon vultures (30) were the most-affected species. There were differences between the two study sites (collision rates 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. Whilst collision *rates* were low, the total number of birds involved, their protected status and the potential cumulative collision victims at other wind farms 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. The most important conclusion of this study is that not all the wind turbines caused the same impact, so the assessment of optional locations and layout is the most important element to minimize the final impact on birds once a wind farm is constructed.

2.57 In the Altamont Wind Resource area, California, USA, there are over 7000 turbines (Orloff & Flannery 1992). Carcase searches found 182 carcases in sample sites around the Altamont Pass Wind Resource Area between 1989 and 1991, of which 119 were raptors. 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 39 golden eagles alone per year.

2.58 The results of studies, such as those referred to above, have contributed to decisions on wind farm 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 wind farm on land adjoining the SPA (June 1999). Population Viability Analysis by objectors to the case indicated that there was between a 5% to 20% chance of mortality from the wind farm causing a decline in the over-wintering population of the Greenland white-fronted geese (McCulloch 1998).

Implications of Collision Mortality - Population Models

2.59 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. 1998, 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 wind farms increase mortality, i.e. have an additive effect.

2.60 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. in PNAWP PM-II 1998). Survival and transition between age-categories are also included in the density-dependent model. This work will require a long timescale in view of the lifespan of golden eagles and year-to-year variability and is in its early stages at present.

2.61 Whilst the use of 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 wind farm proposals. However, in the case of Altamont, the scale of raptor mortality warranted radical measures as one of the two most notable wind energy locations (the other being Tarifa in Spain) to highlight the potential damage that poorly-sited wind farms can cause.

2.62 Sensitivity analysis was used to determine the effect s 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 c omponent of assessments of the influence of wind farms on populations.

Collision Risk and Mortality Offshore

Summary

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

2.64 The importan ce of wind farm layout in determining the risk of collision by birds with wind turbines is just as apparent from offshore studies, as for onshore ones.

2.65 In good weather conditions, during daylight, common eiders were observed to avoid flying and land ing within 100m 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 n ights, compared with moonlit conditions. Nocturnal flight activity, especially on moonlit nights, was reduced in the vicinity of the wind farm, with a diminishing effect observed up to 1000 -1500m away from the nearest turbine. Within 500m from the wind f arm, relatively more groups of common eiders flew around rather than between the turbines. Birds approaching the wind farm parallel to the alignment of turbines were more likely to cross the park than if the approach was perpendicular to the alignment. T hus, wind farms can act as barriers to bird movement, although whether this is a problem will depend on the size of wind farm, 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 wind farm;
- that turbines should be grouped so as to avoid alignment perpendicular to main flight paths;
- the provision of corridors – potentially a fe w kilometres wide - between groups of turbines to allow passage by birds; and
- deep placement of turbines to avoid shellfish beds.

2.66 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 potential ly more significant than they would be for species of short longevity and high breeding productivity.

2.67 *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). However, lighting is likely to be required for navigation (a flashing white light at 10m asl on the turbines for ships and a permanent or flashing light at the top of the turbines for aircraft) (Noer et al. 2000), in which case intermittent lights may reduce the risk of attraction (Richardson in PNAWPPM III 2000). Furthermore, a cluster of turbines will re duce 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 com bined requirements of navigational safety without introducing an unacceptable collision risk for birds either (discussion point at FuglsØ conference, Denmark, November 2001). This is an aspect that requires further study.

2C. Offshore Bird Distribution a nd Movements

2.68 There follows a discussion of the information requirements and availability for assessing distributions, determinants of distribution and collision risk of birds at sea.

2.69 The species groups of most conservation concern offshore are seabirds, waterbirds (notably waders and wildfowl) and migrants. Information is variable about concentrations of birds offshore and especially of migratory movements. There are reasonably complete 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.

2.70 Currently, whilst it is possible to give an indication of some areas of high, medium or low conservation concern, information is limited. For example, 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 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).

2.71 The distance offshore that offshore wind farms 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) 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 and the proportion coinciding with the height of the turbine blades, also are essential for assessing the potential for conflict with wind turbines, either as a result of collision or barriers to movement.

2.72 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 2000, OSPAR). Determinants of winter distributions are more difficult to assess.

2D. Direct Loss of Habitat

2.73 Direct loss of habitat, for wind farm infrastructure, is not generally perceived to be a major concern for birds, depending on local circumstances and the scale of land-take required for the wind farm and associated infrastructure. 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 a restriction of the available habitat, for example as a result of new roads. Also, the opening of new roads in such remote locations might represent an important additional impact, for example enabling generally increased access. However, local hydrology may be detrimentally affected in sensitive habitats, e.g. peatland soils (see para. 2.76). Direct loss of habitat is potentially important in forest habitats, where wind farms and their associated infrastructure require removal of the vegetation.

2.74 Offshore, generally, direct habitat loss is small-scale, primarily for turbine bases and cables at sea. The type of anchorage used (gravity – sunk concrete cassions, drilled or piled monopiles) will affect the scale of habitat loss. It is not thought that the extent of habitat loss associated with offshore wind farms currently proposed is a serious concern for birds, but it may become so as increasingly large wind farms are promoted offshore, or in particular local circumstances e.g. sandbanks in shallow waters. Habitat change or degradation, arising from changes in sedimentary processes, may be significant if large numbers of turbines are sited on sandbanks (see para. 2.80) that are valuable foraging locations. The cumulative loss of such habitat may become a significant factor, especially if multiple, large developments are sited in such locations, and may be additive to disturbance exclusion.

2E. Other Issues

Platforms for Roosting, Nesting, Colonisation

2.75 It is thought unlikely that the turbines will offer many roosting or nesting sites for birds as turbine design now offers minimal opportunity for perching and, offshore, the platforms will be largely submerged. However, access walkways may attract occasional birds to settle, bringing them into close proximity to the turbines. There will be limited exposed surface for marine infauna to colonise, if drilled or piled structures are used. These aspects will require further study to clarify the extent of use and whether or not there is an issue of concern. Large gulls are attracted to loaf on top of the flat-topped nacelles in the Tunø Knob wind farm, Denmark (pers. obs.) and cormorants have been observed on landing platforms at offshore installations (Sundberg, pers. comm.).

Hydrology & Geomorphology

2.76 This is of considerable concern in some locations, onshore especially on peatland soils where turbine anchorage and access roads may interrupt site hydrology.

2.77 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 wind farm 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 (see below). 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, cumulative effects on hydrology arising from multiple, large-scale wind farms might be significant.

Disruption of Seabed and Prey Availability Offshore

2.78 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. 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.

2.79 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 wind farms 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 wind farm by greater food abundance, for example terns and gannets whose plunge-diving feeding behaviour may bring them into the rotor swept area of turbines. Also, such fisheries refuges may nonetheless attract fishing vessels into the area.

2.80 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 wind farm. 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 first phase offshore wind farms 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.

Pollution Offshore

2.76 This is likely to be of minimal concern, but relates 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.

The Future Offshore

2.77 Most studies to date have been of wind farms comprising small wind turbines (=500kW), often in small clusters (1-10). The development of the offshore industry is likely to see substantial increases in the size of turbines (already 2MW installations and prospect of 5MW 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 wind farm 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) as an area requiring study.

3. ENVIRONMENTAL ASSESSMENT AND SITE SELECTION GUIDELINES

3.1 This part of the report provides headline guidance on criteria for environmental assessment and precautions for site selection of wind farms. A more detailed analysis of environmental assessment criteria is provided in the annex to the report.

3.2 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 Wind Farm Development and Nature Conservation (WWF-UK 2001). This also provides useful guidance on how to respond to wind farm proposals, especially in relation to site protection status. Although written from an England perspective, it has relevance elsewhere.

Criteria for Environmental Assessment

3.3 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 basis of the available information (ie existing and collected specifically for the 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 minimise any adverse impacts.

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

i. 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 [8] (see annex).

ii. If screening determines that the project should be subject to an environmental impact assessment (EIA), then this should be carried out to the highest standards using current best practice as set out in the annex to this document.

iii. In the offshore environment, all wind energy projects should be subject to EIAs unless and until an adequate information base exists to permit screening.

iv. EIA must be initiated early in the project planning process and should incorporate full consultation with relevant government bodies and Non-Governmental Organisations (NGOs).

v. 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 to this document.

[8] 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 (79/409)), then an Appropriate Assessment, as set out in Articles 6(3) and 6(4) of Directive 92/43 will also be required.

vi. 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.

vii. 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.

viii. If there are any other projects (other wind farms 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 wind farm development in conjunction with these other projects (see annex).

ix. 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 the Annex to this document[9]. In addition, the EIA should identify compensation measures to compensate for any residual damage, in the event that a potentially/actually damaging wind farm nonetheless is consented.

x. 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 for monitoring framework).

Sensitive Species

3.5 On the basis of the literature review and more than 10 years experience by the BirdLife partners, the following species groups and example species are considered to be particularly sensitive, or potentially so, to wind farms (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 environmental assessment:

Species group (e.g. species)	**Disturbance displacement**	**Barrier to movement**	**Collision**	**Direct habitat loss/damage**
Gaviidae, divers (red-throated diver *Gavia stellata*, black-throated diver *G. arctica*)	v	v	v	
Podicipedidae grebes (red-necked grebe *Podiceps grisegena, Slavonian grebe P. auritus)*	v			
Sulidae gannets & boobies			v	
Phalacrocoracidae (shag *Phalacrocorax aristotelis*)				v
Ciconiiformes herons & storks			v	
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*)	v		v	

[9] 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.

Mergini seaducks (eider *Somateria mollissima*, long-tailed duck *Clangula hyemelis*, common scoter *Melanitta nigra*)	v	v	v	v
Accipitridae raptors (honey buzzard *Pernis apivorus*, white-tailed sea eagle *Haliaeetus albicilla*, lammergeier *Gypaetus barbatus*, gryffon vulture *Gyps fulvus*, marsh harrier *Circus aeruginosus*, hen harrier *C. cyaneus*, Montagu's harrier *C. pygargus*, imperial eagle *Aquila heliaca*, golden eagle *A. chrysaetos*, Bonnelli's eagle *Hieraetus fasciatus*)	v		v	
Charadriiformes waders (Eurasian curlew *Numenius arquata*)	v	v		
Sternidae terns			v	
Alcidae alcids/auks (guillemot *Uria aalge*)	v		v	v
Tetraonidae (black grouse *Tetrao tetrix*, capercaillie *T. urogallus*)	v		v	v
Gruidae cranes			v	
Otididae bustards	v		v	v

Precautions for Site Selection for Wind Farms

3.5 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 wind farm development:

i. Adverse impacts on wildlife must be avoided by full evaluation of suitable alternatives, appropriate siting and design (see annex section on mitigation).

ii. Renewable energy developments must not have an adverse effect on designated or qualifying international (eg. Natura 2000 – SPAs & SACs, or 'Ramsar sites'[10]) and national sites, Important Bird Areas[11] (IBAs), Emerald Network[12], or other areas with large concentrations of birds, such as migratory flight paths, or species identified as being of conservation concern.

iii. There should be precautionary avoidance of areas as defined in 2. above[13], unless and until research indicates that such development is compatible with the favourable conservation status of habitats and species in these areas.

iv. Placement of wind farms in suitable industrial areas, harbour complexes and on agricultural land should also be considered in addition to more traditional upland and coastal sites.

v. Strategic Environmental Assessment (SEA) should inform strategic site selection of wind farms.

vi. Offshore, there is a limited extent of shallow water areas to accommodate the burge oning wind energy industry, especially in the light of nature conservation sensitivities, within and outwith protected areas. Moving turbines further offshore in some areas needs to be considered.

Recommendations

3.7 There is an urgent need for marine pro tected areas to be identified and designated, so that informed decisions can be made on the location of offshore wind farm development.

[10] As designated under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran 1971), as amended by protocol of 1982.
[11] As identified by BirdLife International in their European IBA programme - Heath & Evans (2000).
[12] As designated under the Bern Convention.
[13] In relation to precautions 2 & 3, there is an urgent need for st atutory designation of marine nature conservation areas.

3.8 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 wind farms. This will be an iterative process that will inform decision-making, appropriate site selection and wind farm design. The results of research should be published in international scientific journals, including a summary, preferably in English, to ensure wider dissemination.

3.9 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 wind farm layout and turbine design to provide mitigation.

3.10 National governments should undertake Strategic Environmental Assessment (SEA) [14] 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 also be determined by consideration of the likely biological scale of impacts as well as jurisdictional boundaries.

3.11 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.

3.12 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.

3.13 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.

3.14 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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Natuurpunt – BirdLife Belgium

Norsk Ornitologisk Forening (NOF)

Royal Society for the Protection of Birds (RSPB)

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[14] 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*'.

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6. USEFUL WEBSITES

www.alterra.nl (Alterra, formerly IBN-DLO)

www.bmu.de/english/download/renewable/files/offshore.pdf

www.buwa.nl (Bureau Waardenburg)

www.crownestates.gov.uk/marine

www.dti.gov.uk/renewable

www.dmu.dk

www.nationalwind.org

www.nrel.gov/wind/avian.html

www.offshorewindfarms.co.uk

http://www.ices.dk/reports/occ/2002/

http://www.hornsrev.dk/

http://orn-lab.ekol.lu.se/birdmigration/

7. ANNEX: ENVIRONMENTAL ASSESSMENT

Key European Union Legislation

7.1 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)

7.2 These have important roles to play in directing the assessment of environmental impacts of wind farms.

7.3 Additionally, in the EU, the following Directives inform decision -making procedures for development affecting 'Natura 2000' sites [15]:

- *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 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 of 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) and the Conservation of European Wildlife and Natural Habitats (Bern Convention) confer international responsibilities on signatories for migratory species.

Screening

7.4 Within the EU, selection criteria for screening for 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 wind farm and whether there is potential for cumulative effects with other projects
- The environmental sensitivity of the area likely to be affected by the wind farm
- The extent of the impact of the wind farm, its magnitude, probability, duration, frequency and reversibility.

Environmental Impact Assessment

7.5 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 wind farm, 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:

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

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[15] 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 (79/409),

7.7 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.

7.8 Standardised study methods should be applied, although some site-specific or species specific adjustments may be necessary, e.g. a different sample design may be necessary on large versus small sites, targeted survey methods for some species.

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

7.10 Lack of knowledge, especially offshore, hampers the ability to objectively assess the impacts of wind farms. Information from autecological 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 (*Melanitta spp.*).

7.11 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 wind farms are not considered likely to pose a threat to conservation.

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

7.13 Impacts may operate at different spatial scales. The effects of local changes in abundance and distribution of birds in relation to wind farm 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, wind farms 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

7.14 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

7.15 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.

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

7.17 Significance also cannot be judged purely 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.

7.18 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* and notes on proposals that affect Natura 2000 sites that follow.

7.19 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

7.20 This is an essential, but often inadequately covered, component of wind farm EIA. Cumulative effects may arise from multiple wind farm proposals or from the wind farm proposal and other types of development. A cumulative impact assessment should include all projects that have been developed, or are planned for the area surrounding the proposed wind farm site [16]. Using collision mortality for illustration, effects may be *additive* - increasing overall mortality; or *compensatory* - replacing other causes of mortality; or *synergistic* – increasing mortality over and above the separate, individual developments; or may increase to a critical *threshold level*. 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.

7.21 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?*

7.22 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

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

Mitigation

7.24 Where a detrimental impact is identified, or there 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.

7.25 Mitigation is likely to take the form of modifications to the layout of the wind farm, 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).

[16] 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*' for guidance on this.

7.26 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.

7.27 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

7.28 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. habitat loss in the offshore environment.

7.29 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[17]. 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.

7.30 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 wind farm 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.

7.31 It should be noted that compensation for adverse impacts on a Natura 2000 site (within the EU) only come 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.

Study Protocols

7.32 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 wind farm development. 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.

7.33 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 wind farm site to obtain more representative 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 wind farm site plus buffer and at least one comparable reference, or control, area, matched as closely as possible to the wind farm site. Studies should adopt the Before-After Control-Impact (BACI) approach (e.g. Anderson et al. 1999).

7.34 The assessment of impacts attributable to wind farms is complicated by both 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

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

time will be needed to enable an informed judgement to be made about the effects of wind farms. Cumulative impacts must be assessed.

7.35 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.

7.36 The importance of early baseline studies to identify whether there are potential conflicts with nature conservation interests on a proposed wind farm 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 wind farm and provide the baseline for subsequent comparison if the wind farm proceeds.

7.37 Sites with species of concern will require studies before, during and post-construction on consented sites, using standard methods to monitor distribution and density over time (transect or point counts), and behavioural studies (fixed point observations) to assess site use and collision risk/mortality. Fixed point observations (Morrison 1998) should be made from the minimum number of observation points to cover the wind farm 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.

7.38 The sampling design should enable representative sampling of the wind farm area and reference/control area(s) and ideally provide enough data points to permit statistical analysis. Sampling intensity may be increased at times of particular concern, e.g. raptor breeding season, peak migration times. Longer-term monitoring, at least at a representative group of wind farms, 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.

7.39 Most onshore studies of collision risk/ mortality have involved a combination of observations of flight behaviour (visual and radar plus recording of calls). Corpse searches need to be frequent and data require correction for scavenger removal, search effort and cause of death. 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. Mathematical collision risk models have been developed to assess collision risk (Tucker 1996a & b), but such models can be tested only with appropriate input data and with an understanding of the determinants of site use. 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.

7.40 Offshore development of wind farms is in its infancy and efforts are being made to avoid the problems that have arisen with poorly sited wind farms 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 (Projektgruppe OffshoreWEA 2001, Exo et al. 2002), and the Netherlands (Dutch government) 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 [18] 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, 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); and

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

- studies of collision risk and mortality, for which infra -red video technology is being developed and tested (eg Kahlert et al. 2000).

7.41 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 200km^2 each, although if proposed sites =50km^2, a study area of 200km^2 could comprise both impact and reference areas. In addition, the proposed wind farm site should be overlapped by a minimum 25% buffer zone all round (ICES 2002). [19]

7.42 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 i ncluding 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 ESAS, but they cover limited sea areas per unit time.

7.43 Observations of flight behaviour pre - and post-construction are a necessary for assessment of collision risk and collis ion 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 (Exo et al. 2002). Developments in the use of infra-red video cameras are likely to be especially useful offshore, for recording flight response close to turbines and collisions (Desholm pers. comm., Kahlert et al. 2000). Both these techniques, and image intensifiers may be usefully applied onshor e too.

[19] NB This draft report is subject to review by the relevant ICES Science Committees during the Annual Science Conference and Statutory Meeting, 29 September – 9 October 2002, and is cited here on that understanding .