



Strasbourg, 26 August 2013
[Inf15e_2013.doc]

T-PVS/Inf (2013) 15

CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE
AND NATURAL HABITATS

Bern Convention Bureau Meeting

Strasbourg (17 September 2013)

WIND FARMS AND BIRDS: AN UPDATED ANALYSIS OF THE EFFECTS OF WIND FARMS ON BIRDS, AND BEST PRACTICE GUIDANCE ON INTEGRATED PLANNING AND IMPACT ASSESSMENT

- Final -



*Document prepared by
Report prepared by BirdLife International on behalf of the Bern Convention
Gove, B., Langston, RHW., McCluskie, A., Pullan, JD. & Scrase, I.
RSPB/BirdLife in the UK*

*This document will not be distributed at the meeting. Please bring this copy.
Ce document ne sera plus distribué en réunion. Prière de vous munir de cet exemplaire.*

CONTENTS

EXECUTIVE SUMMARY	4
RECOMMENDATIONS	8
GLOSSARY & ACRONYMS	10
GLOSSARY OF SPECIES	11
INTRODUCTION	12
PART 1 : REVIEW OF THE LITERATURE	13
<i>1.1 Introduction</i>	13
<i>1.2 Displacement</i>	14
1.2.1 Wintering Waterfowl and Waders	15
1.2.2 Breeding Waders	15
1.2.3 Passerines	16
1.2.4 Raptors	16
1.2.5 Other species	17
1.2.6 Micro-turbines	17
1.2.7 Offshore	17
<i>1.3 Collision Risk</i>	18
1.3.1 Evidence of Collisions	20
1.3.2 Micro-turbines	21
1.3.3 Offshore	21
1.3.4 Migration	23
<i>1.4 Habitat Loss or Damage</i>	23
1.4.1 Onshore	24
1.4.2 Offshore	24
<i>1.5 Barrier Effects</i>	24
1.5.1 Onshore	25
1.5.2 Offshore	25
<i>1.6 Indirect Impacts</i>	25
1.6.1 Onshore	26
1.6.2 Offshore	26
<i>1.7 Miscellany</i>	26
1.7.1 Other project related impacts	26
1.7.2 Sensitivity Indices	26
1.7.3 Missed Opportunities and Knowledge Gaps	27
PART 2: INTEGRATED PLANNING AND ASSESSMENT	28
<i>2.1 Introduction</i>	28
<i>2.2 Site Selection</i>	28
2.2.1 The Strategic Approach	28
2.2.2 Sensitivity Mapping	34
2.2.3 Site Selection Protocols	37

2.3	<i>Environmental Impact Assessment</i>	39
2.3.1	Principles of Environmental Impact Assessment	39
2.3.2	Risk Assessment and Allocation of Risk: Determining Significance.....	43
2.3.3	Cumulative Impact Assessment.....	44
2.3.4	Mitigation Measures and Enhancement.....	46
2.3.5	Assessment and Monitoring.....	50
2.3.6	Best Practice Study and Analysis Protocols	51
2.4	<i>Integrated Planning Processes</i>	62
2.4.1	The Benefits of Early and Pro-active Consultation and Joint Working.....	62
2.4.2	Decision-Making and Uncertainty	65
2.4.3	Decision-Making on Projects within the EU Affecting Natura 2000 sites	66
2.4.4	Adaptive Management Frameworks	67
2.4.5	Dissemination of Results	67
	Recommendations	68
	Acknowledgements	69
	References	69
	Useful websites, webpages and online reports	83
	Appendices	86
	Appendix 1 – Key Legislation and Conventions	
	Convention on the Conservation of Migratory Species of Wild Animals (CMS)	86
	AEWA.....	86
	Bern Convention	88
	Ramsar Convention.....	88
	OSPAR.....	89
	Boxes - Case studies	
	Box 1: Displacement and collision of White-tailed Eagles at Smøla wind farm, Norway	19
	Box 2: Investment delays due to lack of strategic planning for wind power in Slovenia	28
	Box 3: The Future of the Atlantic Marine Environment project and offshore renewables.....	30
	Box 4: The need for strategic planning for wind power development in Romania and Bulgaria	31
	Box 5: Failing to take the environment into account: The example of Spanish regional government planning for wind power	32
	Box 6: Offshore wind farm development in Spain	33
	Box 7: Bird sensitivity mapping in the UK.....	35
	Box 8: Bird sensitivity mapping in Greece	36
	Box 9: The Italian reaction to inadequate application of the Habitats Directive tests	37
	Box 10: Habitat enhancement at Whitelee wind farm, Scotland	42
	Box 11: Working between government, industry and NGOs for biodiversity-friendly wind power in France.....	63
	Box 12: Budapest Declaration on power lines and bird mortality in Europe.....	63
	Box 13: The European grid Declaration on Electricity Network Development and Nature Conservation in Europe.....	64
	Box 14: Good Practice Wind project	64
	Box 15: Planning control to stop the worst proposals: The case of Lewis wind farm in Scotland....	66

EXECUTIVE SUMMARY

This report is an update of ‘*Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues*’ (Langston & Pullan, 2003) that was presented to the Standing Committee at its 23rd meeting, and which informed Recommendation 109 (2004) on minimising adverse effects of wind power generation on wildlife.

In the ten years since the original report, there have been advances in wind energy technology and considerable further work on the science of wind energy/avian interactions. Likewise, with the rapid growth of the wind energy industry in Europe, there has been a corresponding development of the policy environment and best practice for strategic planning and project development for wind energy. This new report attempts to bring these developments together in one place to help further understanding of potential conflicts and how these can be minimised to facilitate further growth of the wind energy industry whilst protecting and enhancing Europe’s bird populations.

REVIEW OF THE LITERATURE ON WIND TURBINE/AVIAN INTERACTIONS

This report concentrates mainly on the literature since 2003, literature previous to that date being summarised in the original report. As in 2003, the analysis identifies the following key areas of interaction:

- Displacement;
- Collision mortality;
- Habitat loss or change;
- Barriers intercepting movement; and
- Indirect effects on prey availability.

Displacement

Displacement and disturbance of birds can occur during construction, operation and decommissioning of wind turbines, either due to the presence of the structures themselves and/or associated infrastructure or human activity associated with wind farms. The extent of any effects are variable between species and species groups, as is the degree of habituation (if any occurs). However, some generalisations are possible for some species groups both on and offshore. Displacement has potential impacts on breeding productivity and survival. The level of impact will depend on availability of unaffected habitat in the area or region. Long-term studies are still needed to gain a clearer perspective about the extent, duration and significance of displacement effects on birds.

Collision Mortality

Although collision events with birds are generally quite rare, there have been well-noted cases where inappropriately sited wind turbines, together with poor wind farm design, have led to significant collision mortality for sensitive species. Risk is dependent largely on location, topography and species present. Large soaring birds seem to be particularly vulnerable with research showing griffon vulture *Gyps fulvus*, golden eagle *Aquila chrysaetos* and red kite *Milvus milvus* to be at considerable risk. Weather conditions can affect collision likelihood, and the frequency of adverse conditions at sensitive times (e.g. during migration) may be influential. Wind farms in locations intersecting flight routes between feeding and breeding or roosting locations can also significantly increase risk. Empirical evidence of flight avoidance responses to wind turbines remains sparse. Avoidance of entire wind farm areas has been observed by some species offshore, particularly by migrating waterfowl. A combination of the extent of displacement shown by some species (e.g. seabirds and divers) offshore, including avoidance of passing through a wind farm, and typically low flight elevation, may reduce the likelihood of collision mortality. Other species groups appear not to show avoidance (eg: terns, gulls) and from on/near shore observations appear more prone to collision. However, habituation (or attraction) to the presence of wind turbines, if and where it occurs, may increase collision risk over time, if bird use of areas within the wind farm footprint increases.

Habitat Loss

Habitat loss from the turbine footprints is likely to be small, but can add up when associated road and grid infrastructure are included. This may be significant, particularly for large developments sited on sensitive or rare habitats, or where multiple projects affect the same habitat. Hydrological disruption, particularly on peatland substrates, may also risk wider indirect degradation. Offshore, the knock-on effects of habitat change through reef effects can potentially impact negatively on sensitive communities, although such reefs may act as fish aggregating devices thereby providing refuge and foraging opportunities.

Barrier Effects

Barrier effects can be caused by wind turbines disrupting links between feeding/roosting/nesting areas, or diverting flights, including migratory flights, around a wind farm. They have the potential to have fitness costs for individuals (with potential knock-on effects on breeding productivity, mortality and population size) and affect how birds use the landscape, as demonstrated by radar studies. Barrier effects are only likely to be significant for very large projects, or clusters of projects, or in situations where they cause disruption to daily flights, e.g. for breeding birds with high energy demands that cannot be compensated for.

Indirect Effects

Indirect effects on birds may arise through effects on habitats and/or prey species. Effects on prey abundance and availability may be direct, or mediated via changes in habitats. This may increase or decrease habitat and food availability for some bird species and accordingly reduce or increase the magnitude of a particular risk (e.g. displacement or collision risk). The challenge is to assess these indirect effects along with the direct impacts and the difficulty lies in translating an effect, or cumulative effects, into their ultimate impacts.

Integrated Planning and Assessment

The report sets out best practice for the integrated planning and assessment of wind energy development in order to avoid or reduce conflicts with nature conservation interests. Vital elements include:

- Strategic planning of the wind energy industry and the use of best practice protocols for individual project site selection, to avoid or minimise conflicts with nature conservation interests;
- Robust Environmental Impact Assessment, including baseline studies, impact assessment and post construction monitoring; and
- Integrated, inclusive and iterative project development taking full account of potential interactions with nature conservation through the entire project development process.

Strategic Planning of Wind Energy and Site Selection

Strategic Planning is the key activity in mediating between different interests and demands for land/sea use which, if done properly, increases public acceptance of, and reduces conflicts related to, wind energy development. The report highlights examples in Europe where the lack of a strategically planned approach has led to significant delays in the development of the wind energy industry or unacceptable (and unlawful) consequences for internationally important nature conservation assets, leading to long term uncertainty for the industry. In the offshore environment this is also true, and is exacerbated where existing knowledge of the most important sites for birds is patchy. Strategic planning, with associated strategic environmental assessment informed by adequate baseline data is key to the avoidance of project failures, or additional costs and delays from the discovery of internationally important areas late in project development.

Bird sensitivity maps can provide an extremely useful resource to help developers and regulators steer wind energy development away from the most sensitive areas where conflict is likely, or to help them build in the appropriate level of information acquisition into impact assessments and mitigation options. The adoption and use of bird sensitivity maps is essential, as this will reduce conflicts and

project uncertainty. How they are used will vary depending on whether they are guidance documents, or form part of a land-use plan.

Although Natura 2000 sites in the European Union are not ‘no go zones’ for wind energy projects, developers and regulators need to take into account the high levels of sensitivity and consequent need for thorough assessment of projects that will potentially affect such sites. The considerable uncertainty as to the effects that sites within or in proximity to these areas bring, means that precaution is needed in considering potential impacts, unless sufficient evidence of the full extent and consequences of impacts is available.

Avoidance of sensitive areas is the key factor in reducing the potential for conflicts. However, in some instances adaptation of projects through micro-siting of individual turbines and associated infrastructure to take into account usage of the wind farm area by sensitive bird populations (their use of topography, for instance), can significantly lessen or remove the likelihood of impacts.

Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a crucial process to reduce conflict with nature conservation, it allows:

- Developers to identify and modify proposals to avoid, minimise or compensate for impacts on birds and their habitats;
- Regulators to make informed decisions about whether or not consents should be given, and what conditions to impose; and
- The public to engage with project development so that legitimate concerns can be taken into account, leading to greater acceptance and legitimacy of projects through the consents process.

However, poor EIA often leads to uncertainty, conflict and delay in wind energy development.

Scoping processes should include all relevant stakeholders to ensure all relevant issues are taken into account in the assessment, and that the appropriate level of baseline information is gathered. This should also focus EIAs on the key issues that need information and assessment. Developers should seek to follow the avoidance-mitigation-compensation-enhancement hierarchy and demonstrate this through the EIA.

When undertaking assessments, ‘significance’ of impacts is a key consideration, with particular reference to population impacts at the appropriate spatial scale. Cumulative Impact Assessment (CIA) is an integral and important part of the EIA which is often overlooked or poorly implemented. As the industry develops further this will have a rising importance. Multiple small impacts to individual survival and productivity can have a profound impact on sensitive bird populations. CIA needs to include all relevant planned or existing projects that affect the bird populations in question and whose impacts have not been fully mitigated, in order to avoid problems of ‘baseline creep’ (where reductions in population levels due to previous projects are not taken into account and form the baseline population for subsequent EIAs, thereby ignoring cumulative impacts). Regulators need to be aware of and avoid the potential for ‘salami slicing’ whereby developers avoid EIA requirements by splitting large projects into smaller units to avoid screening thresholds.

There are a variety of mitigation measures that can be employed to reduce potential impacts on birds. These include micro-siting of individual turbines and infrastructure to avoid areas used by sensitive species, orientation of rows of turbines in parallel to common flight lines, undergrounding of associated power lines, or modifying turbine type and operation (such as increasing cut-in speeds or using radar/observer early-warning shut-down systems). Careful use of lighting and acoustic deterrence can modify bird behaviour around the wind farm, whilst implementation of management protocols and plans can reduce human disturbance during construction and operation. Finally site management plans can be used to modify habitats in and around the wind farm to reduce risks to birds, whilst enhancing their overall conservation value.

Provision of compensation should always be a last resort, where avoidance and mitigation cannot remove potential impacts. If it includes provision of new habitat this should be in place and working before the damage occurs, should be as close to the removed habitat as possible, and potentially be of

a greater extent than that removed to take into account uncertainties over its utility. Collision mortality 'compensation' may include provision of measures elsewhere to increase populations of a species in a compensatory manner. Compensation for projects that affect Natura 2000 sites in the EU will only be allowable in very limited circumstances, defined by Article 6 of the Habitats Directive.

Baseline monitoring to inform EIA needs to use consistent and recognised methodologies, ideally using a Before After Control Impact (BACI) model, although offshore a Before After Gradient study design may be more appropriate. Baseline surveys onshore need to be undertaken for a minimum one year period, whilst offshore a two year minimum is recommended. Desk-top studies of existing information can be useful to identify potential issues for further baseline study and analysis and to understand the level of scrutiny that the project will need to pass and so the level of information required. Desk-based study cannot, however, be an alternative to field studies specifically addressing the project and its potential impacts. Baseline studies need to include the full wind farm area and a suitable buffer, as well as any control/reference area. Offshore, advances in digital aerial survey techniques now make this a favoured survey method, although it may still need support through complementary boat surveys.

Assessment of impact on populations should always be the end objective of EIA with regards to birds – and over which geographic scale this should apply may be directed by legislation concerning designated sites and protected species (for example, Natura 2000 sites in the EU). Collision risk modelling provides a quantitative method of assessing collision effects, although uncertainty within the modelling framework needs to be accounted for. Continued lack of comprehensive empirical data on avoidance rates still hampers unbiased assessment. The probability of weather events that change these avoidance rates is a key variable that needs to be considered. The use of matrices and models to help assess and predict disturbance impacts is evolving. Population models (including Population Viability Analysis) can be useful tools in aiding this analysis, although they are heavily dependent on the amount of demographic data available. This is likely to be a growing area of development in the coming years, particularly for the offshore wind industry.

Post construction monitoring at wind farms needs to be able to show any short, medium and long-term effects from the project, and address all the relevant impacts identified in the EIA. These studies also need to be designed to evaluate the effectiveness of any mitigation measures and validate predicted impacts presented in the EIA. Displacement monitoring needs to incorporate pre-, during and post-construction surveys using comparable methods and with adequate statistical 'power' to be able to detect change. Mortality monitoring methods, analysis and technology have developed considerably in the last ten years, including the use of trained dogs and improved correction modelling.

Integrated Planning Processes

Co-operation and joint-working between different stakeholders - developers, regulators, scientists and NGOs - are key to ensuring successful development of the wind energy industry in Europe, in harmony with nature. There are now many positive examples where different stakeholder groups have come together to share information, provide joint resources and agree declarations of common ground. In individual project developments, developers should aim to engage relevant stakeholders as early as possible in the process – ideally from site selection onwards. Although important, engagement only through formal consent processes is often too late, and leaves the potential for significant conflicts to have been built into the project design which will be difficult or expensive to resolve. Early and open engagement provides the potential for better projects, with less conflict, better public acceptance, and reduced costs, delays and financial uncertainties.

In some circumstances uncertainties over the extent and significance of impacts on birds from wind energy development can be addressed through mitigation and adaptive management based on post-construction monitoring. However, this approach should not be used to justify granting of consent to unsuitable projects in highly sensitive areas. If the likely impacts on key bird populations cannot be assessed with sufficient certainty, and/or there is uncertainty over the efficacy of mitigation or compensation, then the precautionary principle should apply. Undue consent of damaging projects hampers long-term development of the industry by re-affirming negative stereotypes. It creates

significant risk and uncertainty to developers, financiers and regulators arising from costs associated with legal challenges, potential removal of damaging infrastructure and remediation of damage.

In those projects where mitigation/compensation is appropriate, post-construction monitoring with 'adaptive management' should be required. This means the actual impacts and efficacy of mitigation measures are monitored, and adapted if they are found not to be working as required. This post-consent enforcement is an integral part of the regulator's role and one which is often overlooked. Dissemination of this post-construction data should be a condition of consent, and regulators have a key role to play as a repository and disseminator of this information. In the long-term the use of these data will provide greater certainty to the industry and other stakeholders, facilitating growth of the industry.

RECOMMENDATIONS

Many of the recommendations from the original 2003 report '*Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues*' remain applicable. The following recommendations repeat and expand on those in the original report. Implementation of these measures would, in the authors' opinion, facilitate the smooth further development of the wind energy industry in Europe, whilst ensuring the protection of our internationally important bird populations.

1. There is still a need for governments and their advisors, with the assistance of industry, to carry out coordinated and targeted strategic research on the impacts of wind farms on birds, and the efficacy of mitigation measures and to make this information widely available, so as to inform future project development and decision-making, and reduce uncertainties over wind energy impacts.

- As part of this, regulators should require developers to carry out comparable pre, during and post construction monitoring.
- Governments and industry should work together in partnership to provide a single web-based resource for this information so that it can be used to inform future research and project development.
- There remains the need for widespread survey of Europe's offshore environment and the identification and speedy designation of key marine sites for birds. Governments with adjoining sea areas should work cooperatively to address this issue.
- There is increasing interest in locating wind energy projects in upland forests, especially in Central Europe. Further research is required to identify the effects of these on forest habitats and sensitive forest bird species.

2. Strategic Planning and associated Strategic Environmental Assessment is a key tool for governments to reduce potential conflicts between protected bird populations and wind energy development. This applies both onshore and offshore, and should be a priority for the relevant government bodies. Spatial zoning and site policy criteria, used effectively, can mediate between biodiversity and wind energy interests and ensure that targets are met in both spheres.

- Sensitivity mapping is a powerful tool to inform locational decisions for wind energy development and should be used by regulators and the industry.

3. Environmental Impact Assessment is the key process to enable informed and transparent decision-making. Regulators need to ensure that all potentially damaging projects undergo EIA, that these EIAs are scoped properly and that there are systems in place to ensure these are undertaken by professionally competent ecologists. Inadequate EIA needs to be challenged by regulators, who should ensure they retain staff that are qualified to understand and critically assess these documents.

- Cumulative impact assessment continues to be generally poorly addressed in wind energy EIAs in Europe. Regulators should ensure EIAs assess this adequately, and work with academics and industry to support further work to facilitate the development of workable assessment methodologies.

4. Regulators should use the precautionary approach in decision-making when there is significant uncertainty as to the impacts of a wind energy proposal on sensitive bird populations. Although adaptive management in post-construction monitoring and mitigation is a valid approach, it should not be used to justify consent of development in unsuitable locations where key bird populations may be put at risk.

- Within the EU, there remain significant issues with regulators not properly implementing the tests of Article 6 of the Habitats Directive, where wind energy development is likely to have a significant effect on a Natura 2000 site. National governments and the European Commission should act to ensure training and oversight is provided to address this.

5. Developers should seek to apply an integrated planning approach to project development. A collaborative, open and transparent approach, adopted very early in project development with all relevant stakeholders, has been shown to improve project outcomes, and to reduce costs, delays and uncertainties.

6. Innovative mitigation measures such as increased cut-in speeds and radar-based on-demand shut-down systems should be investigated for inclusion in project proposals when relevant. However, further research is needed into these and other mitigation measures to prove their efficacy.

7. The Standing Committee of the Bern Convention and other relevant Conventions should encourage co-operation between Contracting Parties on migration routes to evaluate cumulative impacts and safeguard key corridors and stop-over sites.

ACKNOWLEDGEMENTS

This document has been partly financed by the government of Switzerland.

GLOSSARY & ACRONYMS

AA – Appropriate Assessment – A negative test derived from Article 6(3) of the Habitats Directive required for plans/project which are ‘likely to have a significant effect’ on Natura 2000 sites in the EU.

AR – Avoidance Rate – A parameter used in collision risk models to account for behavioural responses to wind turbines, which may result in reduced collision risk assessments.

Birds Directive – EU Directive 2009/147/EC on the Conservation of Wild Birds.

CIA – Cumulative Impact Assessment – a process of assessment of the environmental impacts of a project in combination with other similar or different projects which are operational, under construction, in planning, or reasonably foreseeable. It forms an essential part of EIA.

CRM – Collision Risk Modelling – A mathematical approach to risk assessment, which attempts to estimate the level of bird mortality that will occur following construction of a turbine or turbines.

Disturbance/displacement – Birds using a particular area might be affected by disturbance and/or displacement, potentially arising from the presence of turbines or associated infrastructure or from increased human activity (e.g. during construction and maintenance, or where road construction improves recreational access).

EIA – Environmental Impact Assessment – A process of assessment of the environmental, impacts of a plan or project (both positive and negative), often including social and economic considerations. Within the EU this process is governed by EU Directive 2011/92/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment (‘The EIA Directive’) – currently under review.

Habitats Directive – EU Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna.

IBA – Important Bird Area – A site classified by BirdLife International as an internationally important site for migrating, wintering or breeding birds. They form the basis of the Special Protection Area network, designated under the Birds Directive, in many member states of the European Union.

Macro-avoidance – Reduced flight activity within a particular area as a result evasive action initiated at some distance from the site is termed macro-avoidance. This will usually result in avoidance of a site in totality (e.g. wind farm curtilage/footprint).

Micro-avoidance – Evasive action initiated in close proximity to turbines, e.g. in the vicinity of turbines and within a wind farm curtilage/footprint is often termed micro-avoidance.

Micro-turbines – Typically, micro renewables refers to installations of less than 50 kW generation capacity, for a wind turbine this would usually be less than 25 m in height.

Natura 2000 – The network of Special Protection Areas (designated under the EU Birds Directive) and Special Areas of Conservation (designated under the EU Habitats Directive) which together, form a protected area network which covers over a fifth of the EU.

PBR – Potential Biological Removal – Involves estimating the number of animals that could be ‘removed’ from a population without preventing it from reaching or maintaining its optimal sustainable size.

PVA – Population Viability Analysis – A species-specific method of risk assessment, which can be defined as a process for determining the probability of changes in a population in response to predicted levels of mortality.

SCI/SAC – Site of Community Importance/Special Area of Conservation – Protected area of European importance for the conservation of flora and fauna, designated under the EU Habitats Directive.

SEA – Strategic Environmental Assessment – Environmental assessment of plans or programmes. In the EU this is governed by EU Directive 2001/42/EC on the Assessment of the Effects of Certain Plans and Programmes on the Environment ('the SEA Directive').

SPA – Special Protection Area – Protected area of European importance for the conservation of birds, designated under the EU Wild Birds Directive.

GLOSSARY OF SPECIES

The table below lists the individual species which are referred to by name¹ in the report:

Scientific name	Common name (English)	Scientific name	Common name (English)
<i>Alauda arvensis</i>	Skylark	<i>Gallinago gallinago</i>	Common snipe
<i>Alca torda</i>	Razorbill	<i>Gavia arctica</i>	Black-throated diver
<i>Anser brachyrhynchus</i>	Pink-footed goose	<i>Gavia stellata</i>	Red-throated diver
<i>Anthus pratensis</i>	Meadow pipit	<i>Gyps fulvus</i>	Griffon vulture
<i>Aquila adalberti</i>	Iberian imperial eagle	<i>Haliaeetus albicilla</i>	White-tailed eagle
<i>Aquila chrysaetos</i>	Golden eagle	<i>Lagopus lagopus</i>	Willow ptarmigan
<i>Asio flammeus</i>	Short-eared owl	<i>Larus argentatus</i>	Herring gull
<i>Athene cucularia</i>	Burrowing owl	<i>Larus canus</i>	Common gull
<i>Aythya farina</i>	Common pochard	<i>Melanitta fusca</i>	Velvet scoter
<i>Aythya fuligula</i>	Tufted duck	<i>Melanitta nigra</i>	Common scoter
<i>Aythya marila</i>	Greater scaup	<i>Milvus migrans</i>	Black kite
<i>Branta ruficollis</i>	Red-breasted goose	<i>Milvus milvus</i>	Red kite
<i>Bubo bubo</i>	Eurasian eagle owl	<i>Morus bassanus</i>	Northern gannet
<i>Buteo buteo</i>	Common buzzard	<i>Numenius arquata</i>	Eurasian curlew
<i>Buteo jamaicensis</i>	Red-tailed hawk	<i>Numenius phaeopus</i>	Whimbrel
<i>Calidris alpina</i>	Dunlin	<i>Oenanthe oenanthe</i>	Northern Wheatear
<i>Circus cyaneus</i>	Hen harrier	<i>Phalacrocorax aristotelis</i>	European shag
<i>Charadrius morinellus</i>	Dotterel	<i>Phalacrocorax carbo</i>	Great cormorant
<i>Ciconia nigra</i>	Black stork	<i>Pluvialis apricaria</i>	Golden plover
<i>Circaetus gallicus</i>	Short-toed eagle	<i>Rissa tridactyla</i>	Black-legged kittiwake
<i>Clangula hyemalis</i>	Long-tailed duck	<i>Saxicola torquatus</i>	Stonechat
<i>Crex crex</i>	Corncrake	<i>Somateria mollissima</i>	Common eider
<i>Cygnus cygnus</i>	Whooper swan	<i>Sterna hirundo</i>	Common tern
<i>Falco biarmicus</i>	Lanner falcon	<i>Sterna sandvicensis</i>	Sandwich tern
<i>Falco columbarius</i>	Merlin	<i>Sternula albifrons</i>	Little tern
<i>Falco sparverius</i>	American kestrel	<i>Tetrao tetrix</i>	Black grouse
<i>Falco tinnunculus</i>	Common kestrel	<i>Tringa nebularia</i>	Greenshank
<i>Fratercula arctica</i>	Atlantic puffin	<i>Uria aalge</i>	Common guillemot
<i>Fulmarus glacialis</i>	Northern Fulmar	<i>Vanellus vanellus</i>	Lapwing

The table below lists the bird species groups mentioned in the report:

Order	Family	Common name (English)
Accipitriformes	[Multiple families]	Raptors
Anseriformes	Anatidae	Waterfowl/Wildfowl/Ducks, geese and swans (includes seaducks and scoters)
Charadriiformes	[Multiple families]	Waders and seabirds
	Alcidae	Auks (alcids)
	Laridae	Gulls
	Sternidae	Terns
Ciconiiformes	Ciconiidae	Storks
Galliformes	Tetraonidae	Grouse
Gaviiformes	Gaviidae	Divers
Passeriformes	[Multiple families]	Passerines
Pelecaniformes	Pelecanidae	Pelicans
	Phalacrocoracidae	Cormorants

¹ Nomenclature follows Dudley *et al.* (2006).

INTRODUCTION

Climate change, perhaps more accurately described as climate disruption, is considered to be the most serious long-term threat to biodiversity. Evidence for increasing global average temperatures and sea level rise are compelling, with a high probability that the underlying cause is due to man-made greenhouse gas emissions (Jenkins *et al.*, 2009; UKCP09, 2009). Predicted further increases (Murphy *et al.*, 2009) and their associated consequences are alarming, unless interventions are made now (Usher, 2005; Huntley, 2007). Climate change *per se* is not a new phenomenon, but at this time is characterised by a rapid and unprecedented rate of change (Huntley *et al.*, 2006). Not all species will be able to move, or adapt, quickly enough to changing ecosystems, leading to the likelihood of increased extinction rates. Huntley *et al.* (2007) suggest that the centre of the potential range of the average European breeding bird is predicted to shift nearly 550 km north-east and will be only around 80% the size of the current range. For some species, the potential future range does not overlap with the current range at all; the average overlap is only 40%. Projected changes for some species found only in Europe, or with only small populations elsewhere, suggest that climate change is likely to increase their risk of extinction. Between 15% and 37% of all species may be committed to extinction by 2050 (Thomas *et al.*, 2004).

Renewable energy is an important component of a programme of measures needed to combat further climate change, in addition to measures concerning improved energy efficiency and demand management. Wind power is the most developed renewable energy source currently available (barring hydro-power) and has an important contribution to make to the mix of energy sources required to offset over-reliance on fossil fuels with the associated outputs of greenhouse gases, notably carbon dioxide (CO₂). However, just as with any form of energy generation, wind energy also can have adverse effects on the environment which should be avoided or minimised.

In the intervening years since our previous report, wind energy has developed globally in terms of both installed capacity and technology. At the end of 2012, there were 282 GW installed wind power capacity globally, compared with 39 GW at the end of 2003, when the previous report was produced. European countries account for more than one third of the 282 GW total (GWEC, 2013). Germany (31.3 GW) and Spain (22.8 GW) contributed the largest share of installed capacity, with the United Kingdom (8.45 GW), Italy (8.14 GW), and France (7.56 GW) a little way behind but actively increasing their share (EWEA, 2013). Meanwhile, turbines have also grown in size and output, with 6 and 7 MW machines now under test. Most of the growth has been in terrestrial (onshore) wind farms, but marine (nearshore and offshore) wind farms have increased too, accounting for over 5 GW globally by the end of 2012 (GWEC, 2013). Of the 5 GW of marine wind power 90% was found in Europe, mostly in the United Kingdom and Denmark (GWEC, 2013).

There has been a welcome increase in peer-reviewed scientific studies of the effects of wind energy generation on birds and greater application of scientific methods to impact assessment. Nonetheless, many uncertainties remain, requiring targeted research and monitoring to collect empirical data and further improvements to the assessment of risk to facilitate responsible planning decisions, which protect rather than harm the natural environment.

This report presents an update to an earlier report prepared on request of the Bern Convention (Langston & Pullan, 2003), and comprises two sections; *Part 1* updates the review of literature about the effects of wind energy generation on birds; whilst *Part 2* reviews the issues relating to, and best practice for, integrated planning and assessment, both on land and at sea.

PART 1: REVIEW OF THE LITERATURE

1.1 Introduction

The main potential impacts of wind farms on birds stem from:

- Displacement (and/or disturbance);
- Collision mortality;
- Habitat loss or change;
- Indirect effects on prey availability; and
- Barriers intercepting movement.

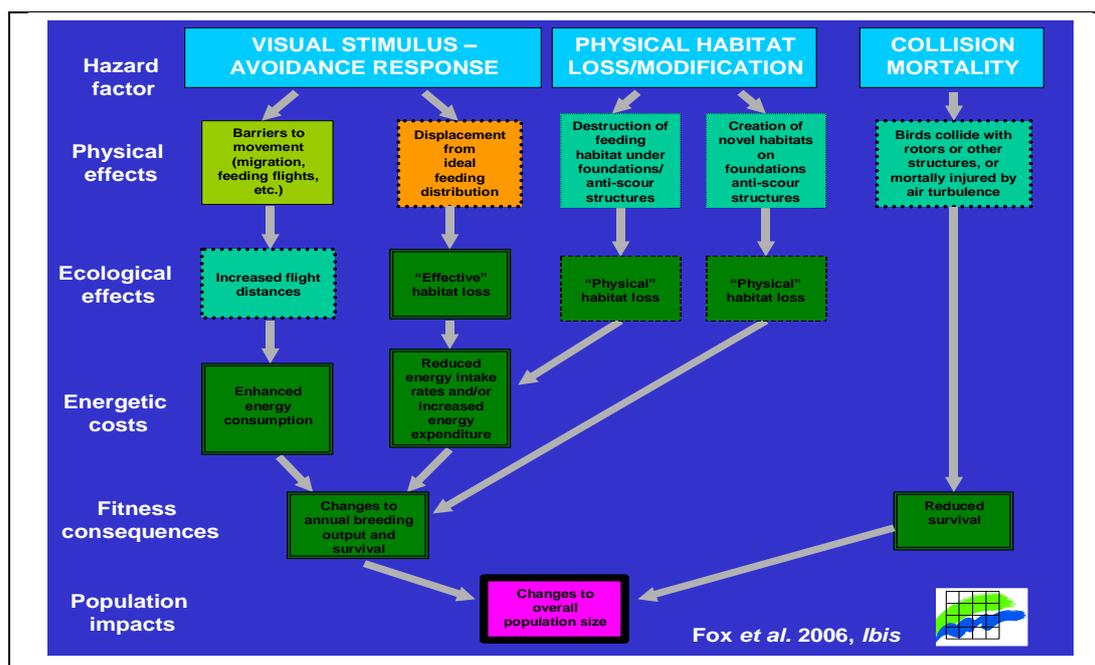
See earlier reviews by Langston & Pullan, 2003; Drewitt & Langston, 2006; Hötker *et al.*, 2006.

The main concerns relating to these potential impacts arise from:

- Wind farms coinciding with concentrations of birds of conservation importance that are vulnerable to any of the factors outlined above;
- Sensitive priority habitats;
- Impacts of wind farms in combination with other developments; and
- Cumulative impacts of multiple wind farms and consequent potential for an effect on bird population sizes.

Collision mortality has a direct effect on individuals, the potential to increase mortality rates and consequently may lead to reductions in population size. Habitat loss or change and disturbance, displacement, or exclusion from areas of preferred or utilised habitat, have the potential to reduce individual fitness or survival, if alternative habitat is unavailable or incurs additional energetic costs, and consequently may lead to reduced breeding productivity and ultimately a reduction in population size. If wind farms intercept major flight paths, for example through displacing migratory flights or flights between breeding, feeding, roosting and moulting areas, there is the potential for increased energetic costs to individuals which, ultimately could lead to reduced fitness or lower survival rates (*Figure 1*).

*Figure 1: Flow chart illustrating risk factors for birds at wind farms² (taken from Fox *et al.*, 2006)*



² This flow chart is specific to offshore wind, but the main risk factors are broadly similar both on and offshore.

The extent to which these impacts manifest themselves is highly site and species specific. Many wind farms have no detectable negative effects and of those that have recorded problems, none so far has been demonstrated to have effects at the level of biogeographic populations. The main concern relates to cumulative effects of multiple installations and poorly sited individual wind farms that lead to unacceptable and often avoidable problems owing to inappropriate site selection or wind farm design. The most notable and well-documented examples of are the Altamont Pass in the USA (Smallwood & Thelander, 2008), Navarra in Spain (Lekuona & Ursúa, 2007) and Smøla in Norway (Bevanger *et al.*, 2010), unfortunately they are not the only examples and more attention to mitigation, most notably in location and design, is necessary.

1.2 Displacement

Displacement is the absence from or reduced use of suitable habitat previously occupied by a particular species, due to changes directly or indirectly brought about due to the development of a project. There may also be disturbance effects which do not lead to displacement *per-se* but do result in impacts with consequences for bird populations. The mechanisms of disturbance and/or displacement of birds by wind farm installations are not fully understood. Disturbance may potentially result from the presence, noise or movement associated with turbines themselves and/or associated infrastructure, their construction, operation and ultimately their decommissioning. However, disturbance also may result from increased human activity and/or vehicle movement (e.g. during construction, removal or maintenance operations, or where road construction improves recreational access by the public). There may also be an increase in predator activity and/or susceptibility of birds to predation, due to improved accessibility and increased disturbance. The effects on birds which are attributable to wind farms are variable and are likely to be species, site and season-specific.

It is difficult (if not impossible) to disentangle the two impacts of disturbance and displacement. Birds might avoid an area altogether (total exclusion), be present but in reduced number (partial displacement), or remain within a wind farm after construction but be subject to disturbance impacts such as reduced fitness, lower productivity or increased predation. The proximate effect of disturbance/displacement of birds from breeding and foraging areas is likely to be reduced productivity, since the breeding season is energetically costly for most birds and at this time they are central place foragers, having to return to the nest regularly to incubate eggs or provision chicks. This restricts their foraging range to a greater or lesser degree, depending on species and ecology (Weimerskirch *et al.*, 1993; Shaffer *et al.*, 2003). Effects on body condition may also influence future productivity and survival. The non-breeding season offers greater flexibility in terms of foraging area for many species, but birds still have energetic limitations, so disturbance and displacement are equivalent to habitat loss and without compensation may lead to increased mortality. Furthermore, there may be a time lag to mortality effects arising from displacement, unlike collision which tends to be immediate.

The range of possible causes of disturbances during the lifetime of a wind farm may include the following (BirdLife International, 2011):

- Construction phase: These may include visual intrusion, noise, vibration, dust, pollution and the physical presence and movement of construction plant (equipment), and the presence of personnel associated with works and site security.
- Operational phase: Visual intrusion of the turbines themselves; noise, movement and shadow flicker; the presence of personnel associated with maintenance and site security; improved access by the public; edge effects of infrastructure (access tracks etc.); and turbines and other structures providing vantage points or improved access for predatory species.
- Decommissioning phase: Visual intrusion, noise, vibration, dust, pollution and the physical presence and movement of construction plant (equipment), and the presence of personnel associated with (de)construction and site security.

Whatever the causal mechanisms involved, disturbance can lead to displacement and exclusion from areas of suitable habitat, which effectively amounts to reduction in quality or loss of habitat for birds, leading to reductions in bird density (Pearce-Higgins *et al.*, 2009). There is evidence that for some species the period of greatest displacement impact is during wind farm construction rather than operation (Pearce-Higgins *et al.*, 2012). However, whilst the local populations of some species showed recovery after construction (for example, willow ptarmigan *Lagopus lagopus scotica*), numbers of other species remained low during the subsequent operational phase (notably breeding waders: common snipe *Gallinago gallinago* and Eurasian curlew *Numenius arquata*), indicating stabilisation at a lower level (i.e. lock-in of displacement) rather than post-construction recovery in bird density/abundance. Only in one species is there firm evidence of a relationship between hub height and avoidance distance; displacement distances for lapwing *Vanellus vanellus* outside of the breeding season increase almost linearly with increasing turbine (hub) height (Hötter *et al.*, 2006).

Even where it is demonstrated, caution is needed in interpreting the consequences of displacement, which depend on both the availability of alternative habitat and the effects on reproduction and survival (Gill *et al.*, 2001). Displacement can lead to reduced fitness and lower productivity (Madsen, 1995), but equally may have little or no impact on population size if birds are able to find equivalent alternative habitat. Intuitively, it might be expected that, if there is a particularly good resource available, such as otherwise undisturbed foraging habitat, birds will adjust over time to the presence of fixed objects such as wind turbines after any initial displacement. Therefore, displacement may be temporary for those species that have the capacity to habituate to the presence of turbines. For example, there is evidence of habituation by pink-footed geese *Anser brachyrhynchus* to the presence of wind turbines in winter foraging habitats (Madsen & Boertmann, 2008). Individual studies have shown habituation in a number of species (see Hötter *et al.*, 2006). However, a systematic review of the effects of wind turbines on birds has indicated that as the period of operation increases there are generally greater declines in abundance (Stewart *et al.*, 2005), suggesting that habituation is unlikely in many cases. However, few studies are of sufficient duration to reliably detect long-term changes in distribution. Indeed, the long-term implications of habituation, if or where it does occur, are not clear. Even if individual adult birds show habituation, younger individuals, which would eventually replace them in the breeding population, may choose to move into areas without wind turbines, so habituation in the short or medium-term may mask adverse effects in the longer-term.

The susceptibility of different types of birds to disturbance/displacement by onshore wind farms can be summarised as follows:

1.2.1 Wintering Waterfowl and Waders

Disturbance distances for onshore wind turbines (the distance from wind turbines in which birds are either absent or the population density is less than expected) up to 850 m have been recorded for wintering waterfowl and waders (e.g. Pedersen and Poulsen, 1991; Kruckenberg & Jaene, 1999; Larsen & Madsen, 2000; Kowalik & Borbach-Jaene, 2001; Hötter *et al.*, 2006; Madsen & Boertmann, 2008). A distance of 600 m is the maximum reliably recorded distance for the majority of species (Langston & Pullan, 2003; Drewitt & Langston, 2006). Assuming an absence of habituation, a precautionary complete avoidance distance would be in the region of 300 m for wintering waders and wildfowl, with a precautionary displacement distance of 600 m; the expected population reductions would be in the region of 100% within 0-300 m and 50% within 300-600 m.

1.2.2 Breeding Waders

Studies of breeding birds have generally indicated smaller displacement distances compared with non-breeding birds (e.g. Hötter *et al.*, 2006; Pearce-Higgins *et al.*, 2009; Bevanger *et al.*, 2010). However, this may be in part due to the high 'site fidelity' displayed by many species (indicated by the return in consecutive years to the same breeding site or territory) and long life-span of breeding species (Drewitt & Langston, 2006). Consequently, the real impacts of disturbance on breeding birds will only be evident in the longer-term, when new recruits replace (or fail to replace) existing birds. In most cases displacement of breeding waders is limited to within 500 m of turbines (Hötter *et al.*, 2006; Pearce-Higgins *et al.*, 2009; 2012; Bevanger *et al.*, 2010), but a few species show a higher

degree of sensitivity, for example Eurasian curlew has been shown to be displaced up to 800 m (Pearce-Higgins *et al.*, 2009).

1.2.3 Passerines

There have been relatively few studies of the displacement of passerines, which are typically short-lived with high productivity rates and therefore are generally not considered to be particularly sensitive or vulnerable at the population level to wind farm impacts. Several authors have found decreased densities of breeding grassland passerines within the vicinity of wind turbines compared with reference areas (Leddy *et al.*, 1999; Pearce-Higgins *et al.*, 2009; Bevanger *et al.*, 2010), indicating that displacement can occur. For example, Pearce-Higgins *et al.* (2009) showed meadow pipit *Anthus pratensis* to be displaced within 100 m of turbines and northern wheatear *Oenanthe oenanthe* to be displaced within 200 m. However, other studies have failed to find evidence to suggest that farmland birds or other passerines avoid areas close to wind turbines (Devereux *et al.*, 2008; Farfán *et al.*, 2009), indicating that displacement responses are species and/or site specific. Indeed, some species of passerines have been shown to benefit from the construction of wind farms (Bevanger *et al.*, 2010; Pearce-Higgins *et al.*, 2012), with increased densities after construction, possibly in response to the creation of suitable (i.e. disturbed) habitat (e.g. bare peat or rocky ground). In the majority of cases where it does occur, the displacement of passerines appears to be limited to within approximately 100-200 m of turbines (e.g. Hötker *et al.*, 2006; Pearce-Higgins *et al.*, 2009).

1.2.4 Raptors

Displacement of foraging/hunting raptors has been demonstrated in a number of species (Hötker *et al.*, 2006; Farfán *et al.*, 2009; Pearce-Higgins *et al.*, 2009; Smallwood *et al.*, 2009). Minimum distance to turbines (i.e. the distance within which complete exclusion was observed) are variable and species specific (Hötker *et al.*, 2006; Pearce-Higgins *et al.*, 2009). Flight activity has been shown to be reduced within 500 m of turbines by 40-50% for some species (e.g. common buzzard *Buteo buteo* and hen harrier *Circus cyaneus*), but to be unaffected for others (e.g. common kestrel *Falco tinnunculus*) (Pearce-Higgins *et al.*, 2009). Conversely, the flight activity of some species has been shown to increase in the vicinity of turbines (Barrios & Rodriguez, 2004; Smallwood & Thelander, 2004; Smallwood *et al.*, 2007; 2009).

There have been few published studies of breeding raptors in the vicinity of wind farms (e.g. Dahl *et al.*, 2012). Such studies have demonstrated displacement of raptors from breeding territories by wind turbines, although there are occasional accounts of raptor nests within or in close proximity to wind farms (e.g. Janss, 2000; Dahl *et al.*, 2012; Whitfield & Leckie, 2012). However, in many cases the displacement of foraging raptors described above is likely to impact nest site selection as well, and where existing nest structures are located in areas of wind farm development, abandonment may be the net result. Research into the impacts of a wind farm on Smøla has demonstrated a decrease in occupied white-tailed eagle *Haliaeetus albicilla* territories after construction (Bevanger *et al.*, 2010). The extent to which territory abandonment is due to collision mortality or displacement in this case is unknown, although there is some evidence that both play a part (Dahl *et al.*, 2012). White-tailed eagles are long-lived species, displaying high levels of territorial fidelity (albeit there may be several nest site locations within a single territory), and aggression to establish territories and pairs, which are likely to explain those cases of continued occupancy of territories within the wind farm. In the UK, hen harriers are known to nest within a few hundred metres of wind turbines (Whitfield & Leckie, 2012), but the impact on nesting success is not known. Minimum displacement distances for foraging raptors appear to be in the order of 100-200 m for many species (e.g. Pearce-Higgins *et al.*, 2009). However, the presence of suitable habitat (e.g. for foraging, roosting and/or nesting) might result in higher levels of activity than in surrounding areas, particularly if the occurrence of such habitat is spatially limited. In addition, disturbance of nests (for example by maintenance personnel) might be an issue with species showing varying degrees of sensitivity to disturbance, and flight activity is likely to be higher in close proximity to the nest. Therefore, the avoidance of known nest site locations is frequently recommended for raptor species (e.g. Bright *et al.*, 2009).

1.2.5 Other species

There is some evidence for displacement of willow ptarmigan during wind farm construction (Pearce-Higgins *et al.*, 2012) however, as discussed above numbers recovered during the post construction period. Other post-construction studies have failed to show displacement for this species, for example densities inside the Smøla wind farm are similar to densities on control areas, and there was no indication of any differences in productivity for the two populations (Bevinger *et al.*, 2010). Therefore, it appears that displacement of this species is short lived.

1.2.6 Micro-turbines

There is a paucity of information on the impacts of micro-turbines on birds. Only one study to date has investigated the interactions between small wind turbines and birds (Minderman *et al.*, 2012). This work indicated that the operational status of, or distance from, small-scale turbines (hub height 6-18 m) did not affect observed bird activity at the fine scale (0-25 m). However, it would be unwise to assume that there is no displacement of any bird species by micro-turbines, based on the results of one single (relatively small) study, which did not examine the effects on individual species.

1.2.7 Offshore

Empirical data for displacement in response to wind farms in the marine environment are sparse and equivocal. Study methods also vary and are not always clearly documented so studies may not be directly comparable. Furthermore, study design is critical to the statistical power to detect change (Degraer *et al.*, 2012; Maclean *et al.*, 2006; 2007; 2013) but is often not adequate for this purpose. Study site selection is also critical to the ability to detect any change that might occur. For example, it was concluded that up to 10 years of post-construction monitoring would be required to detect a 50% change in abundance of northern gannet *Morus bassanus* and common guillemot *Uria aalge* at Thorntonbank and Bligh Bank offshore wind farms, in Belgium, given the levels of activity at the sites by these species (Vanermen *et al.*, 2011; 2012). The power analysis of the 12 seabird species included in the study also revealed that even after 15 years of impact monitoring at this site, a 25% reduction in numbers would not be detected with a power greater than 55%, for any species. Interestingly, analysis carried out in 2011 comparing the pre-construction period (1993-2007) to the post-construction period (2008-2010), indicated no significant difference in the numbers of northern gannet or common guillemot at either site (Vanermen *et al.*, 2011). But when data from the following year (2011) was included, the statistical power was sufficient to indicate a significant reduction in the numbers of both species at both sites (Vanermen *et al.*, 2012).

Seaducks and divers are noted for their susceptibility to disturbance, especially in response to boats (Schwemmer *et al.*, 2011). Sensitivity indices, based on species' ecology, ranked divers and common scoter *Melanitta nigra* as most vulnerable and included common eider *Somateria mollissima*, common guillemot, razorbill *Alca torda* and European shag *Phalacrocorax aristotelis* as moderately vulnerable to disturbance/displacement in response to offshore wind farms (Furness & Wade, 2012; Furness *et al.*, 2013).

Effects on bird density, notably for divers and seaducks, indicating displacement from areas occupied by wind turbines, have been observed at several offshore wind farms, in shallow waters. Data from aerial surveys carried out before, during and following construction of the Horns Rev 1 and Nysted offshore wind farms, in Denmark, were used to evaluate possible displacement effects of wind turbines on birds. Distributional changes within the wind farm, the wind farm area plus 2 km radius and the wind farm area plus 4 km radius were assessed. Divers and common scoters showed almost complete avoidance of the Horns Rev 1 wind farm area in the first three years post construction, with a significant reduction in density noted up to 4 km (Petersen *et al.*, 2006). Significant effects up to 2-4 km beyond the wind farm were observed during the 3 years post-construction, for black-throated diver *Gavia arctica*, red-throated diver *G. stellata* and common scoter, at Horns Rev I offshore wind farm, and for long-tailed duck *Clangula hyemalis* at Nysted (Petersen *et al.*, 2006). Further surveys in 2007 found no change (i.e. no signs of habituation) for divers, but common scoters appeared to be present in comparable densities within and outside the wind farm (Petersen & Fox, 2007). Reduced use was also noted post-construction up to 2 km from the Nysted wind farm by divers and scoters (Petersen *et al.*,

2006), up to 2 km from the Gunfleet Sands 1 & 2 wind farms in the Outer Thames estuary, UK, for red-throated divers and auks, and for red-throated divers up to 3 km from the Kentish Flats I wind farm in the Outer Thames estuary, UK (Percival, 2010; Rexstad & Buckland, 2012). The possibility cannot be excluded that changes in food availability rather than the mere presence of wind turbines led to the observed changes in distribution (Petersen & Fox, 2007), although the weight of evidence from several sites indicates an effect of wind turbines. These studies emphasize the value of longer term studies to enable a distinction between short-term and longer term effects. They indicate the potential for cumulative effects arising from large-scale development of offshore wind farms within the wintering and passage ranges of these species, given their association with shallow waters (e.g. Mendel *et al.*, 2008).

Larsen & Guillemette's (2007) experimental studies at Tunø Knob offshore wind farm, in Denmark, indicated that wintering common eider reacted to the visual presence of the wind turbines. Flight trajectories and the likelihood of landing on the water, in response to the presence of decoys, were both significantly influenced by the proximity of the wind turbines; fewer eiders flew or landed closer to turbines. Neither the total numbers of flying or landing birds, nor their distribution, were affected by the operational state of the wind turbines. The authors identified the need for further studies of feeding ecology and the extent to which food availability is a limiting factor determining the distribution of wintering seabirds. Such avoidance may reduce collision risk for species that otherwise would be at risk of collision, but in the absence of equivalent alternative feeding areas leads to displacement impacts. At the scale observed in this study, such displacement is unlikely to lead to an adverse effect, but in the case of larger wind farms or multiple wind farms displacement could be a cause for concern.

Studies undertaken at Princess Amalia and Egmond aan Zee nearshore wind farms in the Netherlands found differing levels of partial displacement of common guillemot and razorbill, some significant others not significant, that were greater in response to the larger Princess Amalia wind farm which had higher turbine density and is slightly further offshore (Leopold *et al.*, 2011; Hartman *et al.*, 2012). During the first year of operation of the Robin Rigg offshore wind farm, displacement of 30-32% was observed for common guillemot, compared with the pre-construction situation. This study relied on boat-based surveys over the wind farm footprint and a large reference area surrounding the wind farm, and the use of density surface modelling (Rexstad & Buckland, 2012; Walls *et al.*, 2012). Studies at Horns Rev 1 comparing Jacobs Preference Index (-1 complete avoidance to +1 complete attraction) indicated reduced density of common guillemot/razorbill (there was poor species distinction from aerial surveys) post-construction, particularly in the wind farm and surrounding 2 km area but out to a distance of 4 km from the wind turbines (Petersen *et al.*, 2006). Numbers of auks were highly variable and they found no statistically significant difference in encounter rate pre- and post-construction. However, common guillemot and razorbill were absent from the Horns Rev 1 wind farm area post-construction.

The variability in observed results for common guillemot/razorbill highlights the need for robust study design using appropriate methods and sampling protocols for data collection and appropriate analytical techniques to increase the likelihood of detecting an effect where there is one, and to facilitate the distinction between inherent variability between sites from apparent variability due to methods. The study by Vanermen *et al.* (2011; 2012) detailed above neatly encapsulates the need for studies of sufficient duration and power to detect changes.

1.3 Collision Risk

While there are scant data on the processes that determine collision risk, there now exists a widespread consensus that birds sometimes do collide with turbines, and that under certain circumstances wind farm related mortality can induce population level effects (Langston, 2013). In particular, certain birds of conservation concern may be vulnerable to collision with wind turbines, because of behaviour and location-related factors. Local population level effects can be a risk for such species due to their population status and/or ecology. The main bird groups at risk of collision are large raptors and other large soaring species, as well as some migrating birds (Langston & Pullan, 2003). Since raptors tend to occur at relatively low densities, and are long-lived with low reproductive outputs, any additive mortality from collisions can have adverse population scale effects at a local

level, and could potentially affect biogeographic populations of vulnerable species (Drewitt & Langston, 2008; Carrete *et al.*, 2009), although such effects have not yet been demonstrated at a biogeographic level.

Relatively high collision mortality rates have been recorded at several poorly sited wind farms in areas where high concentrations of vulnerable birds are present (including some IBAs), for example golden eagle *Aquila chrysaetos* in the USA, griffon vulture *Gyps fulvus* in Spain and white-tailed eagle in Norway. Red kite *Milvus milvus*, an endemic European species with a small global population, is particularly threatened by wind farm developments. This species commonly occurs in the German wind turbine collision record (Bellebaum, *et al.*, 2013). Based on carcass searches, Bellebaum *et al.* (2012) modelled an annual mortality from turbine collision of at least 3.1% of the population in one of the core areas of the species' range in Germany.

The most important risk factors are location, topography and species present. Other factors such as wind speed and direction, air temperature and humidity, flight type, distance and height, time of day all influence the risk of collision, as do age, behaviour and stage of the bird's annual cycle (Langston & Pullan, 2003). All these factors need to be incorporated in collision risk assessments, to make meaningful predictions.

Collision risk is likely to be greatest in poor flying conditions that affect the birds' ability to control flight manoeuvres, or in rain, fog, and on dark nights when visibility is reduced (Langston & Pullan, 2003). In these conditions, flight height, particularly of migrating birds, tends to be greatly reduced. Factors such as lighting of turbines (and/or infrastructure) has the potential to attract birds, especially in bad weather, thereby potentially increasing the risk of collision, depending on the type of lighting used (Drewitt & Langston, 2008), however, raptors do collide even under best light conditions (see Section 1.3.1).

Box 1 - Displacement and collision of White-tailed Eagles at Smøla wind farm, Norway

Background: The Smøla Archipelago lies off the west coast of central Norway, and comprises a main island surrounded by many islets and skerries. BirdLife International identified Smøla as an Important Bird Area for its high breeding density of white-tailed eagles, among the highest in the world (Heath & Evans, 2000) and so a likely source population. Research carried out in 1999 for the EIA (by the Norwegian Institute for Nature Research, NINA) for a proposed wind farm indicated that this was a potentially problematic, notably for breeding white-tailed eagles. The Norwegian government took the view that any impact would be limited and local in character and that the wind farm would not be in conflict with Norway's responsibilities under international conventions. Consequently, it granted permission, subject to a phased development, and several other measures including the removal of four turbines from the original proposal, undergrounding a section of powerline, and a programme of monitoring territory occupancy and productivity of white-tailed eagles. NOF-BirdLife, the Norwegian BirdLife partner, took the case to the Bern Convention but was unsuccessful in getting the necessary support to overturn the decision. Subsequently, the Bern Convention agreed to an on-the-spot appraisal, which was undertaken by E. Kuijken in June 2009.

Dr. Kuijken made several recommendations: to establish an SEA for wind energy development in Norway; ensure good quality EIA, incorporating recommendations on EIA and mitigation from the BirdWind study; introduce mitigation measures at Smøla, including time-critical turbine shutdown and reduction of powerline-induced mortality; suspend the Norwegian wind energy programme, pending completion of the BirdWind study and site-specific and regional CIA; investigate the possibilities of future non-renewal of the licence for the Smøla wind farm, or renew for a shorter time period and plan for ecological restoration of the site; compensate for wind farm expansion in Norway by speeding up designation of new conservation areas.

These recommendations, discussed at the 29th Standing Committee meeting, in 2009, received a mixed reception and there were strongly held views that the Smøla wind farm offered opportunities for studies to deliver 'best practice' for application at Smøla and other wind energy projects, and that such studies would be compromised by any cessation of operation. However, the Committee agreed not to open a case file on this issue but adopted the Recommendation No. 144 (2009) on the wind park in Smøla (Norway) and other wind farm developments in Norway. The monitoring of the implementation of the Recommendation was carried out in 2010 and 2011. A new monitoring report will be requested for the 33rd Standing Committee meeting in 2014.

Smøla wind farm: The Smøla wind farm comprises two parts. Phase 1 of 20 turbines (2 MW) was constructed in 2001/2002 and became operational in September 2002. Phase 2 of 48 turbines (2.3 MW) was constructed in 2004/2005 and became operational in August 2005. The 68 turbines occupy approximately 18 km², and there

are 28 km of roads.

Norwegian Sea Eagle Project: There is a long history of monitoring sea eagles (i.e. white-tailed eagles) in Norway. For over 30 years, the Norwegian Sea Eagle Project has been monitoring occupancy and productivity of sea eagle territories across Norway, including Smøla (NOF-BirdLife). This provides background, contextual information for Smøla. Detailed population and productivity monitoring within the wind farm area was carried out in 2001, for the EIA, and from 2003 onwards (NOF-BirdLife/Norwegian Institute for Nature Research (NINA)). Beyond this, there was very little by way of monitoring of the Phase 1 wind farm and Phase 2 proceeded.

Research: NINA commenced a study of collision mortality, using trained search dogs, in 2006, and a collaboration between the RSPB and NINA, commenced in the same year, focusing on collision risk and behavioural responses to wind turbines by white-tailed eagles (May *et al.*, 2010; Douglas *et al.*, 2012; RSPB, unpublished). The Norwegian BirdWind Project (2007-2010) soon followed, incorporating studies of bird collision mortality, dedicated studies of white-tailed eagle and willow ptarmigan *Lagopus lagopus*, surveys of breeding waders and passerines, radar ornithology, and initial investigation of mitigation technology (Bevanger *et al.*, 2010).

Studies of white-tailed eagle at the Smøla wind farm, between August 2005 and December 2010, found a prevalence of collision mortality in spring, comprising mainly adults (13) and sub-adults (10), but also returning first-year birds (5) (Bevanger *et al.*, 2010). Of the 39 collision fatalities found during this study, 11 were associated with just 5 of the 68 turbines, all situated along the NW edge of the wind farm.

Dahl *et al.* (2012) analyzed 10 years' of data from monitoring white-tailed eagle territory occupancy on the main island of Smøla, as part of a before-after-control-impact (BACI) study. Pre-construction data for 1997–2001 and post-construction data for 2005–2009, from 47 eagle territories, were analyzed using a generalized linear mixed model. The most parsimonious model, explaining a large proportion of the variance in the data ($\omega_1 = 0.629$), was that run for territories included from the year of establishment onward, irrespective of subsequent abandonment. Dahl *et al.* (2012) found that predictors of breeding success were time period (before and after construction), turbine distance (inside the wind farm, defined as the turbine envelope plus a buffer of 500 m beyond the outermost turbines, or outside this area; i.e., in the control area), and the interaction between these terms. Notably, they found that breeding success in the wind farm territories was higher pre- than post-construction, and 8 of the 13 territories were deserted following completion of the wind farm. Dahl *et al.* (2012) suggested that a combination of collision mortality and displacement is the likely cause of the reductions in white-tailed eagle territory occupancy and breeding success within the wind farm. They have found a displacement of the area of higher territory density away from the centre of the wind farm and their DNA analysis indicates that at least some of the white-tailed eagles that collided fatally with wind turbines formerly held territories within the wind farm (Bevanger *et al.*, 2010).

The Smøla studies illustrate the potential for both displacement and collision mortality effects to affect a species. The Smøla wind farm merits long-term monitoring and research to determine the ongoing effects of the wind farm on breeding success and recruitment, although it also offers the opportunity to test whether any effective mitigation measures can be applied. In view of proposals for further wind farms within the breeding range of this species, there is a risk of cumulative impacts, leading to a change in population trajectory from one of growth to stabilisation or decline (e.g. Carrete *et al.*, 2009).

1.3.1 Evidence of Collisions

Numerous studies, and a number of reviews report on bird mortalities, either through direct collision with turbines, or by being forced to the ground having been caught in vortices associated with rotating turbine blades (e.g. Carrete *et al.*, 2009; Bevanger *et al.*, 2010; Garvin *et al.*, 2011; Ferrer *et al.*, 2012; Rees, 2012). Mostly such mortalities have been at low levels, but there have been some areas, notably Navarre and Tarifa in Spain (Lekuona & Ursúa, 2007; Ferrer *et al.*, 2012), Altamont Pass in North America (Smallwood & Thelander, 2008) and Smøla in Norway (Bevanger *et al.*, 2010; see *Box 1*) where reported collisions have been relatively high. Raptors seem more likely to collide with turbines than many other species due to morphology and flight behaviour. In the examples above the species involved in the largest mortalities were, respectively, griffon vulture in Spain, golden eagle, red-tailed hawk and American kestrel *Falco sparverius* at Altamont Pass and white-tailed eagle at Smøla. Collision risk for griffon vulture has been found to be, counter intuitively, greatest at low wind speed even during daylight and good visibility (Barrios & Rodriguez, 2004). The absence of thermals in winter forces many raptors including vultures to use slopes for lift (Pennycuick, 1989), which is likely to influence their exposure to turbines set on ridge lines. In addition to the increased

exposure, their low manoeuvrability (coupled with relatively weak flapping flight) increases the risk of mortality in low wind speeds (de Lucas *et al.*, 2008). The flight activity of some species has also been shown to increase in the vicinity of turbines after construction, often as a result of habitat changes, e.g. golden eagle *Aquila chrysaetos* (Smallwood & Thelander, 2004); burrowing owl *Athene cunicularia* (Smallwood *et al.*, 2007); and red-tailed hawk *Buteo jamaicensis* (Smallwood *et al.*, 2009); offshore species such as common gull *Larus canus* (Vanermen *et al.*, 2011) have also shown to be attracted by turbines, such increases might lead to higher than expected collision rates.

Collision rates per turbine are highly variable from site to site and can even vary greatly between turbines within sites. Quoted collision rates per turbine, range from zero to over 60 collision fatalities per wind turbine per year (Drewitt & Langston, 2008). The lowest collision rates are typically associated with grassland and moorland sites, while the highest are associated with mountain ridges and wetlands (Hötter *et al.*, 2006). However, consideration of the species present and their abundance and use of the area, combined with design features of the wind farm are essential. Several attempts have been made to estimate average mortality rates at a wider scale, such as at a national level (e.g. see Rydell *et al.*, 2012; Smallwood, 2013). However, such estimates are inevitably skewed upwards, since corpse monitoring is more frequently carried out at those sites where collision is expected to be a problem than where there are few concerns, and thus estimates are likely to represent worst case scenarios rather than be reflective of the real picture.

A recent review of the collisions of swans and geese with turbines at 46 European wind farms (Rees, 2012) reported 34 swans and 37 geese mortalities. The review suggested that displacement reduced the collision risk of these species, but was critical of the short time scale of the majority of studies. Most were of no more than one year post-construction, and there remains the possibility of greater collision risk if acclimatisation to the presence of turbines occurs. In some cases, longer-term databases of collisions exist at a site or country level (e.g. Germany), although mostly these compile records of chance finds rather than the result of systematic monitoring and therefore are of little use in determining collision rates or of estimating overall mortality. However, it is becoming apparent that certain species are particularly vulnerable to collision, and that certain behavioural, morphological and physiological characteristics are important influences on collision risk. For example, griffon vultures, combine high wing loading and consequent low manoeuvrability (de Lucas *et al.*, 2008) with a small binocular region and large blind areas above, below and behind the head (Martin *et al.*, 2012), thereby increasing their vulnerability. Furthermore local topographic features can also increase vulnerability, for example golden eagles fly at lower altitudes over steep slopes and cliffs, thereby increasing their collision risk (Katzner *et al.*, 2012).

For most species, the primary component of collision is assumed to be with turbine blades, whilst they are in operation. However, there is a growing body of evidence that some species are more prone to collision with other elements of the wind farm infrastructure. For example, there is anecdotal evidence of willow ptarmigan collision with tower bases (Bevanger *et al.*, 2010), and other species are known to have suffered similar fates. In addition, there are occasionally documented examples of collision with static blades, attraction (and subsequent collision) with substations (for example when lit in foggy conditions), and collision with meteorological masts has also been documented. Unfortunately, these contributors to collision mortality do not lend themselves easily to quantification, and so are rarely (if ever) included in risk assessments.

1.3.2 Micro-turbines

There has been little investigation into the impacts of micro-turbines on birds, with only one study published (Minderman *et al.*, 2012). However, the study did not investigate collision mortality. The absence of evidence on the impacts of micro-turbines makes the interpretation of ecological surveys problematic (Park *et al.*, 2013), and it is currently impossible to gauge the likelihood of collision events with micro-turbines. Although it is anticipated that the collision of sensitive species will be generally rare, if micro-turbines are appropriately located.

1.3.3 Offshore

Location remains the most important risk factor, in particular distance offshore and the level of flight activity by species for which, or at times when, elevated collision risk is likely. Generally, we

do not have comprehensive knowledge about the locations of important offshore feeding areas, notably for birds from specific breeding colonies, although we can begin to make some expert judgements about the likelihood of risk. There is a high risk of collision with wind turbines if they are located in areas in which there is a high level of flight activity by birds most likely to collide with turbine rotors or be affected by the associated turbulence. High levels of activity may be due to high prey concentrations or high turnover of individuals using the area. The elevation of the lowest blade sweep is likely to be critical in determining risk. One particular concern in respect of forthcoming proposals for wind energy generation in Europe is their proximity to the breeding colonies of pelagic seabirds, i.e. within their known foraging ranges during attendance at the nest/chick(s) when they are central-place foragers.

There are limited studies of collision mortality at offshore wind farms, largely because of the difficulty of finding carcasses and attributing cause of death. One study, by Newton & Little (2009) attributed just 3% of mortality, mainly of large gulls and common eider, to collision with coastal wind turbines. The study took place at Blyth in NE England, where seven of the nine 300kW wind turbines were located on a harbour breakwater. This study, over 11 years, relied on corpses washed ashore, having experimented with wooden blocks to establish the proportion of corpses likely to be beached. Three mortality events were observed, two large gulls collided with the moving rotors and a northern fulmar *Fulmarus glacialis* hit a turbine tower. Allowing for the proportion of corpses for which cause of death could not be determined, the authors estimated a maximum of 21.5 birds per turbine per year attributable to the wind farm. This study illustrates the challenges associated with obtaining evidence of collisions for offshore wind farms and most studies have focused on collision risk and flight avoidance, using a combination of radar, visual observations and cameras or thermal imaging (e.g. Desholm & Kahlert, 2005; Krijgsveld *et al.*, 2011). Flight avoidance may lead to a barrier effect where wind turbines intercept flight-lines.

Several studies indicate flight avoidance of coastal and offshore wind farms, sometimes initiated at considerable distance from the wind farm, species for which far-field avoidance is recorded include common pochard *Aythya farina*, tufted duck *A. fuligula* and greater scaup *A. marila* (Dirksen & van der Winden, 1998); common eider (Desholm & Kahlert, 2005); migrating seabirds, notably northern gannet (Krijgsveld *et al.*, 2011) and migrating pink-footed goose (Plonczkier & Simms, 2012). Far-field avoidance, sometimes referred to as macro-avoidance (e.g., Krijgsveld *et al.*, 2011), can result in substantial reductions in the numbers of birds entering wind farms. In contrast, studies of gulls, terns and great cormorant *Phalacrocorax carbo* show little or no avoidance of wind turbines (Krijgsveld *et al.*, 2011), and in some cases attraction has been observed (Vanermen *et al.*, 2011), or responses that differ in relation to specific sites (e.g. Petersen & Fox, 2007).

Risk level is a combination of distribution and behavioural characteristics of the species, which may vary seasonally and spatially as well as being age- and sex-dependent (Stienen *et al.*, 2008). For example, the evidence for terns is that they are generally manoeuvrable in flight, but a large proportion of flights occur within rotor swept height. Several wind turbines at Zeebrugge wind farm, in Belgium, were situated along a breakwater, intercepting flights between a tern breeding colony and their marine feeding areas. Collision mortality at this site affected common tern *Sterna hirundo*, Sandwich tern *S. sandvicensis* and little tern *Sternula albifrons* (approx. 50 carcasses found *per annum*) associated with the breeding colony, and gulls commuting to roosts (Everaert & Stienen, 2007). Most tern collisions were with four breakwater turbines and were probably attributable to the increased flight activity into and out of the colony, during incubation and chick-rearing, when time pressures on adult birds lead them to take the most direct flights between breeding and feeding areas (Henderson *et al.*, 1996; Everaert & Stienen, 2007). The elevated collisions of male common terns were attributed to sex-biased variation in foraging activity during egg-laying and incubation (Stienen *et al.*, 2008).

Northern gannets plunge dive from 10-50 m (or more) above the water and large proportion of flight activity is below or within the rotor swept height. They range over large areas and may forage over 100 km away from their breeding colonies, with the potential to encounter several wind farms during a foraging trip. They are considered to be at high potential risk of collision with wind turbines (Furness *et al.*, 2013). Using a combination of radar and visual observations at the Egmond aan Zee wind farm, in The Netherlands, Krijgsveld *et al.* (2011) found pronounced flight avoidance of wind turbines and the whole wind farm, by several species of seabird, notably northern gannet, but little or

no avoidance by other species, especially gulls, cormorants and migrating terns. They also noted avoidance by divers, scoters, auks, and migrating swans and geese. Although samples were small, they observed an increasing proportion of northern gannets flying within the wind farm over the three years of study, and observed birds foraging and diving within the wind farm. Generally, there were relatively low numbers of breeding seabirds in the area into which the Egmond aan Zee wind farm was introduced, with peak numbers occurring during migration. This was a detailed study, but the small size of the wind farm (36 x 3 MW wind turbines in 27 km²) and inshore location (10-18 km offshore) may limit the wider applicability of its results to large, offshore wind farms located within the foraging range of colonial, cliff-nesting seabirds.

Reported collision fatalities must represent only a fraction of the actual mortality levels. However, in many cases collision mortality probably only accounts for low levels of additive mortality (i.e. it may result in the death of individuals, but is only one of several causes of mortality). For example, the study of nesting terns at Zeebrugge, Belgium (Everaert & Stienen, 2007) estimated an increase in background mortality of at least 1.5% (for two species) as a result of birds colliding with turbines that intercepted flights between offshore foraging areas and their nests. As with birds of prey, most seabirds are long-lived species and even small increases in mortality, especially of breeding adults, can impact populations. Individual wind farms may lead to increases in local mortality, and the potential for reduction in population sizes is most likely in situations that lead to ecological sinks (populations maintained only by immigration) or as a result of the cumulative effects of multiple wind farms across the geographical range and main habitats of a vulnerable species.

1.3.4 Migration

Little is known about the effects of wind turbines on diurnal or nocturnal migrants, especially during take-off and landing adjacent to wind turbines (for example, during migration stopover) and during inclement weather. Both phenomena put birds at direct risk of collision (Langston & Pullan, 2003; Newton, 2007; Drewitt & Langston, 2008). Whilst flight activity is often depressed in poor weather, birds caught in bad weather after initiating migratory flights are likely to reduce their flight height, and may land on the sea, or divert/reverse their migration to the nearest landfall (e.g. whooper swan *Cygnus cygnus*) (Pennycuik *et al.*, 1999; Griffin *et al.*, 2010). Krijgsveld *et al.* (2011) observed high levels of avoidance of the Egmond aan Zee near-shore wind farm, in the Netherlands, by nocturnally migrating passerines, whereas 50-75% of diurnal migrants flew within the wind farm, at rotor height, although most groups were observed to avoid individual turbines. Waders on migration also showed little avoidance of the wind farm.

Plonczkier & Simms (2012) reported a strong horizontal and vertical avoidance by pink-footed geese at the Lynn and Inner Dowsing offshore wind farms off the east coast of Britain, which thereby reduced their collision risk, although it is not known whether any geese collided. However, cumulative effects from further wind projects have yet to be assessed (including any associated increased energy demands on the geese) toward the end of their southbound migration. Plonczkier & Simms (2012) also noted that migrating geese increasingly flew inshore of the wind farms in successive years. Eight studies of flight behaviour by swans and geese, reviewed by Rees (2012) indicated changes in flight direction at distances ranging from a few hundred metres, for local birds commuting between feeding areas and roosts, to 5 km for migrants, to circumnavigate wind farms; 50-100% of flocks/individuals avoided entering the wind farms, although sample sizes were small.

Radar studies at Nysted indicated a high degree of avoidance of the wind farm by large waterbirds during migration, mainly common eider (Desholm & Kahlert, 2005). The avoidance response was initiated at greater distance from the wind farm during daylight (≤ 3 km) than at night (≤ 1 km). Similarly, radar and visual observations at Utgrunden and Yttre Stengrund, in the Kalmarsund, Sweden, indicated that most migrating common eider avoided flying close to small clusters of wind turbines (respectively 7 and 5 turbines in parallel with the main direction of migration) (Pettersson, 2005). This study provides a rare observation of collision or turbulence effects for individuals in a flock of common eiders. A flock of approximately 310 common eider, in V-formation, flew past an outer turbine when several individuals in the outer flank, and therefore the rear, of the flock struck the rotating blade on its downward trajectory or were caught in the associated turbulence. Four birds were observed to fall into the water, of which at least two flew out and at least one was killed. This

example illustrates the fact that turbulence around the rotors may pose a hazard and that birds do not necessarily have to be struck by the rotor blades for flight impediment or fatality to occur.

1.4 Habitat Loss or Damage

The loss of, or damage to, valuable habitat resulting from the development of wind farm infrastructure is not generally perceived to be a major concern for birds outside designated or qualifying sites of national and international importance for biodiversity. The scale of direct habitat loss resulting from the construction of a wind farm and associated infrastructure will depend on the size of the project, but, generally speaking, is likely to be small per turbine base (Drewitt & Langston, 2006). Typically, actual habitat loss amounts to around 2-5% of the total development area (Fox *et al.*, 2006). However, depending on local circumstances and the scale of land-take required for the wind farm and associated infrastructure (including roads, transformers etc.), cumulative impacts on sensitive habitats may be significant, especially if multiple developments are sited in vulnerable habitats. In certain habitats wind energy development might have more widespread impacts, such as through hydrological or micro-climatic changes, edge effects or the introduction of alien species.

Habitat alteration and/or creation also may result in increased opportunities for species, which may be beneficial, or detrimental depending on the situation. For example, Pearce-Higgins *et al.* (2012) showed increased numbers of skylark *Alauda arvensis* and stonechat *Saxicola torquatus* within wind farms, probably as a result of vegetation disturbance during construction. On the other hand, changes in habitat management can increase foraging opportunities (and flight activity) by raptors, resulting in increased collision risk.

1.4.1 Onshore

In several documented cases, erosion and large-scale slumping has taken place following construction (e.g. Lindsay & Bragg, 2005), leading to more extensive habitat damage. Even relatively small-scale destruction and fragmentation of priority habitats in protected areas can be significant, for example, Ponto-Sarmatic steppe habitat in Bulgaria and Romania, and habitat fragmentation may modify ecological patterns, thereby increasing the influence of edge effects (Batary & Baldi, 2004). Furthermore, direct habitat loss may be additive to other impacts such as displacement and barrier effects.

There has been little investigation of the impacts of wind farms in forested landscapes, although in several European countries there are a number of factors leading to the regular location of wind farms in forests. There could be a particular set of impacts associated with wind energy developments within forest environments, centring around factors such as habitat loss, fragmentation and edge effects, increased collision risk for species inhabiting the forest canopy, higher levels of disturbance and potentially increased fire risk.

1.4.2 Offshore

Direct habitat loss is relatively small scale for individual turbines. However, associated infrastructure, sub-stations and cables all add to the loss or damage to existing habitat for a wind farm and is of concern for sensitive habitats of conservation importance and the species that depend upon them, including prey species for birds. Loss, change or damage to sensitive habitats may extend beyond the immediate footprint of the wind turbines, although scour and effects on coastal processes and sediment transport tend to be localised (ABPmer *et al.*, 2008). Topographical features that concentrate birds, e.g. shallow waters and sandbanks are features that may pose particular conflicts between birds and wind farm development. For example, shallow-submerged sandbanks are recognised as a priority habitat by the EU Habitats Directive, but are also attractive to developers of offshore wind farms because of the shallow water. Floating turbine technology may remove the dependence on these shallow water habitats.

Wind energy installations can introduce new habitats, which like other structures placed on the seabed, tend to attract benthic colonists (see *Section 1.6*). This can allow the expansion of native benthic communities, which is likely to be generally positive (unless it increases the flight activity of bird species vulnerable to collision risk), but such structures might also provide stepping stones for invasive (alien) species, which is likely to result in negative outcomes.

1.5 Barrier Effects

The effect of birds altering their migration flyways or local flight paths to avoid wind farms is another form of displacement known as the ‘barrier effect’. This has the potential to increase energy expenditure (Masden *et al.*, 2010) or may result in disruption of linkages between distant feeding, roosting, moulting and/or breeding areas (Drewitt & Langston, 2006). The effect depends on a range of factors: species and type of bird movement (e.g. foraging, commuting, migrating) including flight height and avoidance of turbines; the location, layout and operational status of the wind farm; time of day and visibility; wind force and direction; topography. It can be highly variable, ranging from a slight change in flight direction, height or speed, through to significant diversions, which may result in increased energetic costs resulting in lower reproduction and survival (e.g. Masden *et al.*, 2010) and/or reduce the numbers of birds using areas of suitable habitat beyond the wind farm (Drewitt & Langston, 2006).

1.5.1 Onshore

There is a growing body of evidence that wind turbines may act as barriers to movement of some bird species in the offshore environment, with birds choosing to fly around the outside of clusters, instead of between turbines (Exo *et al.*, 2003; Drewitt & Langston, 2006). Where radar studies are available for onshore wind farms (e.g. Farfán *et al.*, 2009) there is evidence of similar patterns of behaviour for many species. Farfán *et al.* (2009) showed that more flights occur parallel to turbine rows than across them in the majority of species (except passerines).

There are currently few if any examples of birds being excluded from key areas due to barrier effects, mainly because onshore wind farms tend to be reasonably isolated (from each other) and are often fairly discrete (in terms of geographic extent). However, the cumulative effects of large numbers of wind turbine installations may be considerable if birds are consequently displaced from preferred habitat or such detours become significant in terms of energy expenditure. Such scenarios become more likely as the number of wind farms increases.

1.5.2 Offshore

Birds may fly around, rather than between, clusters of wind turbines, thereby increasing the energetic costs of flight and or disrupting ecological links between feeding, roosting, breeding and moulting areas, and extending migration routes (Exo *et al.*, 2003; Drewitt & Langston, 2006). The magnitude of the increase in energy expenditure will depend upon the number and size of wind farm(s) along the flight route and the spacing of turbines, as well as the weather conditions and the extent of deviation from the preferred route. It is not necessarily the case that flight deviation will significantly increase the overall flight distance, especially for migrants, nor that there will be a significant increase in energy expenditure. The barrier effect will be problematic if birds cannot compensate for any increased energy expenditure by increasing their food intake or, in the case of migratory flights, do not carry sufficient fuel load or are forced to make an additional stopover which may not be in suitable feeding habitat. Consequences for individuals are unlikely to impact upon populations except as a result of the cumulative effects of multiple wind farms.

So far, documented flight deviations have not been of sufficient magnitude to infer such a problem (e.g. Desholm & Kahlert, 2005). Masden *et al.* (2009b) found only trivial increases in energetic costs of flight deviations around wind farms for eiders migrating >1,400 km. As illustrated by the Everaert & Stienen (2007) study, frequent foraging trips by seabirds during the breeding season, especially when provisioning young, may either increase collision risk or lead to a barrier effect where wind turbines intercept flights between nesting and foraging areas, depending on whether birds are more or less likely to display avoidance behaviour. Masden *et al.* (2010) modelled the energetic costs of additional travel distance, based on daily energy expenditure in the breeding season, for 9 seabird species representing the range of foraging ecology and flight morphology, and found considerable variation among species. Terns displayed the greatest relative increase in energetic costs owing to the high daily frequency of foraging flights they need to make to feed their chicks.

1.6 Indirect Impacts

Indirect effects on birds may arise through effects on habitats and/or prey species. Effects on prey abundance and availability may be direct, or mediated via changes in habitats. This may increase or decrease habitat and food availability for some bird species and alter accordingly the magnitude of a particular risk (e.g. displacement or collision risk).

The challenge is to assess these indirect effects along with the direct impacts and the difficulty lies in translating an effect, or cumulative effects, into their ultimate impacts (Masden *et al.*, 2009a). To date the assessment of indirect impacts is rarely if ever a serious part of the EIA process.

1.6.1 Onshore

There are a variety of ways in which onshore wind turbines may exert indirect effects, mediated either through habitat changes or changes in prey densities. For example, wind turbines can have micro-climatic effects, such as changes in down-wind surface temperatures (Roy & Traiteur, 2010; Walsh-Thomas *et al.*, 2012) which could result in ecological impacts, resulting in changes of prey-availability. In terms of direct effects on prey resource for birds, the species attracted to the area around the wind turbine bases may in turn attract birds to feed. For example, there is evidence from the Altamont Pass in the USA that changes in the behaviour of cattle in response to wind turbines has increased the risk for several bird species (e.g. burrowing owl) responding to increased availability of prey resources owing to the shorter sward and increased dung (Smallwood *et al.*, 2007).

1.6.2 Offshore

There are indications that offshore wind farms may act as refugia for fish and other marine organisms, especially where restrictions are placed on shipping and fishing activities, although it remains unclear whether this is simply redistribution or if it will increase populations/resources. Hard substrates associated with the turbine structures and scour protection are colonised rapidly, as with other similar structures at sea, and provide new habitat (Lindeboom *et al.*, 2011), although whether this is beneficial or not depends on the habitat being replaced and the species that are introduced as part of these new faunal communities. The turbine platforms also provide roosting and loafing surfaces for various birds, notably cormorants and gulls (Lindeboom *et al.*, 2011).

1.7 Miscellany

1.7.1 Other project related impacts

Environmental Impact Assessments for wind energy projects should include all potential sources of impact. Not only those directly attributable to the proposed wind turbines themselves. As discussed in *Section 1.3.1*, collision with other elements of wind farm infrastructure (e.g. meteorological masts, turbine towers, sub-stations etc.) also occur. For example, there is ample evidence that power lines pose a significant threat to the populations of certain species (e.g. Haas *et al.*, 2005; Prinsen *et al.*, 2011a). Many species which are vulnerable to collision with wind turbines are also at risk of collision (or electrocution) with powerlines or other infrastructure. However, such impacts are often considered in isolation and not in-combination with more readily quantifiable effects such as collision risk or displacement from a wind farm footprint.

1.7.2 Sensitivity Indices

The pressure to develop offshore wind farms in a relatively short timeframe and in the absence of understanding of the effects on birds, prompted the production of a sensitivity index for birds, which was then applied to the German sectors of the North Sea and Baltic Sea (Garthe & Hüppop, 2004). The species sensitivity index, based on ecological understanding and expert judgement, provides a useful measure to assist in prioritising bird species for risk assessment and further study. The highest ranked species were divers, followed by velvet scoter *Melanitta fusca*, Sandwich tern, great cormorant and common eider.

A revised wind farm sensitivity index, incorporating peer-review, has been applied to seabirds in Scottish waters (Furness & Wade, 2012; Furness *et al.*, 2013), although it has wider applicability. The main improvement, compared with Garthe & Hüppop's (2004) index, is the development of separate

indices for collision risk and displacement. Furness *et al.* (Furness & Wade, 2012; Furness *et al.*, 2013) calculated the displacement score thus: (Disturbance score x Habitat flexibility score x Conservation importance score)/10. The highest ranked species were divers and common scoter. The species collision sensitivity index was calculated thus: Percent flying at blade height x 1/3 (Manoeuvrability score + % Time flying score + Nocturnal flight score) x Conservation importance score (ranked by index value). The highest ranked species in their collision risk index were large gulls, white-tailed eagle and northern gannet.

1.7.3 Missed Opportunities and Knowledge Gaps

There are a number of knowledge gaps which could have been addressed using the early rounds of development sites as case-studies/research platforms. This would have put the industry on surer footing today, as some of the uncertainty currently surrounding the deployment of wind energy installations would be absent or greatly reduced. This requirement for good quality research and monitoring is even more urgent in the case of offshore wind deployment, where developing the knowledge base is more challenging.

However, it is not too late to develop a co-ordinated approach to monitoring, research and assessment of wind farm and bird interactions to inform future developments and ensure that the industry is and remains environmentally and ecologically sustainable as it grows. The following list includes some of the areas where research and monitoring efforts can and should be directed:

- Knowledge of bird distributions, abundance and activity during both breeding and non-breeding seasons, including connectivity, notably between wind farms/proposal areas and SPAs/IBAs, as well as bird movements and behaviour;
- Thorough investigation of impacts, particularly collision risk/avoidance, displacement and barrier effects' indirect effects;
- Assessment of cumulative impacts both onshore and offshore;
- Evaluation of risk assessment methods and protocols;
- Development of guidance and standardised approaches to data collection and analysis; and
- Examination of potential mitigation options, further research and field testing.

There is also an urgent need for a coordinated programme of before and after construction monitoring, and access to wind farm sites for collaborative research into the impacts of wind farms. Developers can assist research by making the avian studies from their assessments, together with underlying data, accessible to the scientific community. This could be achieved through the use of a centralised repository for information, for example via an internet-based portal, one for onshore and one for offshore. This would facilitate meta-analysis of post-construction monitoring data from several wind farms as well as longer-term or repeat studies at given time intervals.

There is also a role for licensing authorities/regulators to establish clearer objectives (Kershaw *et al.*, 2012; MMO, unpublished³) and more stringent monitoring requirements, together with timely public release of monitoring reports and associated data to permit independent validation. The co-ordinated approach should apply not only to data gathering, but also to risk assessment (EIA methods) and deployment (e.g. to inform SEA). In order to ensure that the maximum value is obtained from the monitoring and research efforts carried out at individual sites, updated guidance on standardised approaches to data collection and analysis are necessary.

³ The Marine Management Organisation (MMO) and Cefas, on behalf of Defra (UK government) has commissioned a consortium of experts led by Fugro EMU, to provide an independent review of OWF monitoring from the first two rounds of wind farm consents in UK waters, in order to understand the lessons learnt and provide recommendations on improving future licence-related monitoring strategies.

PART 2: INTEGRATED PLANNING AND ASSESSMENT

2.1 Introduction

Part 2 of the report discusses issues surrounding, and best practice for, policy, planning and environmental assessment for wind energy. As such it aims to provide guidance for government regulators, wind energy developers and environmental consultants involved at the different levels and stages of wind energy development. This includes good practice for the spatial planning of wind energy, incorporating the use of sensitivity maps and proposal-specific site selection. Implementation of rigorous impact assessment processes is vital for the successful development of wind energy, avoiding impacts on nature conservation interests. Detailed guidance is given here on best practice for EIA. Finally, consultative and open project development and well-informed decision-making are equally important factors in order to facilitate the smooth continued roll-out of the wind energy industry in Europe, and the integrated planning processes section outlines how this can be achieved.

2.2 Site Selection

Site selection is the key issue to avoid impacts on bird populations from wind energy development. This needs to be addressed at both the strategic level across a whole country or region, and in relation to individual development projects. The following sections set out best practice, with good and bad case examples of how this has been addressed so far in Europe.

2.2.1 The Strategic Approach

2.2.1.1 National and regional planning frameworks – policy and spatial approaches

Good plans steer development so it serves the public interest and do so in ways that best fit the circumstances and needs of the communities on whose behalf (and with whose participation) those plans were developed. Plans do not have to be imposed in a ‘top-down’ manner, and they do not have to impede investment. Done well, planning enables investment because an open, legitimate democratic process is seen to have balanced competing interests and needs, and therefore each proposal for development does not become a flashpoint for debate and protest.

Wind energy development is one area where planning is most justified given the urgency to decarbonise energy supply, and the controversies infrastructure development brings. Moreover electricity provision of all kinds, and particularly from wind energy, is highly geographically specific – it has to take into account existing infrastructures, demand locations and wind speeds. One can argue that developers rather than officials are best placed to understand those factors and to plan investments accordingly. There are many enlightened investors and developers, but their first priority will always be to run a profitable business and make sound investments. They cannot be expected to weigh up the local benefits of one land use over another, nor to consider the wider public benefits for this and future generations. Nor can they be expected to undertake the necessary studies and develop the necessary vision over appropriate time and geographic scales to ensure coordinated and efficient energy system development that minimises overall infrastructure needs and related costs to society and nature.

It falls to elected representatives and public authorities to reconcile different stakeholders’ interests, and failing to do so can prolong conflict and thereby stall investment. This has been the experience in Slovenia with wind power development, where strategic spatial planning has not been developed (*Box 2*).

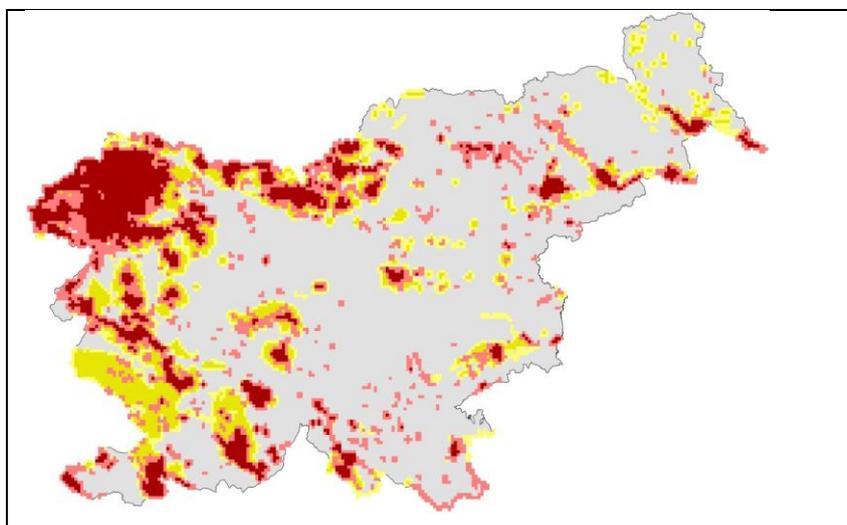
Box 2 - Investment delays due to lack of strategic planning for wind power in Slovenia

Wind power potential in Slovenia is relatively weak. In spite of this, the public electricity corporation launched an ambitious wind-power investment programme in 1999. After a few years of measuring wind speeds, and without further strategic planning, the corporation identified three locations as those likely to be most profitable: Mount Nanos, Mount Golič and Mount Volovja reber. All three mountains are of exceptional landscape beauty and are part of the EU Natura 2000 network. All three sites are designated to protect griffon vultures and golden eagles - species known to be particularly susceptible to collision with wind turbines.

The proposed programme would have led to degradation of some of the most valuable parts of Slovenia's natural heritage, so provoked widespread opposition among nature conservation organisations. In the case of proposed Volovja reber wind farm, where 47 turbines were proposed, an intense conflict developed. After eight years of procedures, and after several court cases lodged by DOPPS/BirdLife Slovenia, the proposal was eventually definitively rejected.

As a consequence of these conflicts, Slovenia has no wind turbines erected so far. The key obstacle is that country has no national strategy or consensus on how and where to develop wind power. In 2006 a coalition of conservation NGOs proposed that the Government should develop a national strategy, identifying sites for wind-power development informed by bird sensitivity mapping. Sadly, the authorities have refused this approach. However, DOPPS continues to call for strategic planning for wind power, and has managed to find funds to produce a sensitivity map (*Figure 2*) relating to seven highly sensitive bird species and 13 moderately sensitive ones. The maps suggests that only 15% of total Slovenian territory is highly sensitive (red) for wind development, while additional 15% is moderately (yellow) sensitive. In the remaining two thirds of national territory it is foreseen that wind farm development would not harm the interests of bird conservation (Bordan *et al.*, 2012)

Figure 2: Bird sensitivity map produced by DOPPs/BirdLife Slovenia



In Bulgaria, the National Renewable Energy Action Plan 2012, as well as setting out how Bulgaria will meet its renewable energy obligations, also directs where further wind energy development should take place. In this case, the government has chosen to exclude further wind energy development from Natura 2000 sites and sensitive locations on the 'Via Pontica' migration route along the Black Sea coast.

As with wind energy infrastructure itself, it is very important to ensure that associated new grid infrastructure and upgrades are also planned in a systematic and transparent way at appropriate spatial scales in order to ensure an efficient network that avoids (or at the very least substantially reduces) risks to sensitive bird populations.

2.2.1.2 Offshore spatial planning for wind power

Spatial planning has a long history in Europe, but is in its infancy in the marine environment. In the UK SEA and mapping of resources and constraints has been used to define areas for licensing offshore wind development in the North Sea. This has been extremely useful to developers, who have shown a very keen interest in investment. The European Wind Energy Association's EU funded project called SEANERGY2020 is developing policy recommendations on marine spatial planning and offshore wind power.

Spatial planning of offshore wind development should, logically, begin after thorough surveys have been completed and marine protected areas have been designated. However, SEA has been used in the North Sea to identify development zones, taking into account available ecological survey data and other factors such as average wind speeds, water depth, seabed geology and constraints such as shipping lanes, important commercial fishing grounds and military zones. In the UK, the process of

Offshore Energy SEAs has enabled the industry to develop rapidly and with reduced risks to wildlife, although in this instance ecological data was considered of lower priority compared with so-called 'hard constraints' such as shipping lanes, oil & gas platforms etc. In addition, given the poor quality of underlying data there is a significant risk to developers that previously unidentified and strictly protected bird species will be identified during EIA survey work.

BirdLife partners were involved in an ambitious project to enable strategic planning for biodiversity-friendly offshore energy exploitation in the Atlantic (*Box 3*).

Box 3 - The Future of the Atlantic Marine Environment project and offshore renewables

Offshore wind farms are already a reality in some countries, such as the UK, but are still new to France, Spain and Portugal. However, it is clear that the next five to six years will witness a rapid increase in the number of proposals in the Atlantic, both for offshore wind farms and wave & tidal energy harnessing. FAME – Future of the Atlantic Marine Environment – was an ambitious strategic transnational cooperative project that ran from 2010-2013, involving partners from five countries (UK, Ireland, France, Spain and Portugal). It engaged with the offshore renewable energy sector in order to facilitate strategic planning and robust assessment of impacts. By facilitating direct communication with key energy stakeholders and linking the scientific, conservation and private sectors, a unique open and honest discussion was enabled. This will help to ensure that key areas are protected for seabirds, while ensuring that sustainable generation of renewable energy is facilitated.

FAME partners gathered and analysed information on seabirds for several years before the initiation of the project, and some partners identified marine Important Bird Areas (IBA) or contributed to the designation of the Natura 2000 network at sea in their countries. The FAME project built on that information and knowledge to generate risk maps, identify the most sensitive areas, produce guidelines and disseminate relevant information to enable sustainable implementation of the renewable sector in the marine environment. The guidelines produced include the identification of negative and positive impacts of offshore energy deployment on seabirds in view of different project phases (installation, exploitation and decommissioning), the development of methodologies for impact prediction and evaluation and the identification of critical impact uncertainties. Mitigation measures have been selected for a range of technologies considering different project phases. A list of recommendations for future baseline and monitoring studies on seabirds is also provided.

FAME benefited from using a common methodology and created a common GIS-based database for all countries to identify hotspots of seabird activity and energy production proposals. The final aim of this assessment was twofold. By providing access to these data to private developers, and engaging with them through this project, future offshore energy developments will be better planned and better able to avoid conflict with key areas for biodiversity. In addition, the data will help governments, NGOs and developers properly assess cumulative impacts caused by offshore energy developments. Cumulative impacts are probably the most difficult threat to assess from a trans-national perspective, as developments in different administrative regions will not always be taken into account when assessing proposals. By providing comprehensive data to all stakeholders, FAME enables impacts on biodiversity across the whole Atlantic Area to be considered.

2.2.1.3 Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) provides the ideal framework for using wildlife sensitivity maps and other environmental information to develop strategic plans for wind energy. It is a publicly accountable process of identifying and assessing alternative ways to meet a plan's objectives, ensuring that the final plan provides for a high level of protection to the environment. Environmental authorities are consulted on the scope of the SEA, to ensure relevant alternatives, baseline information and impacts will be addressed. Assessment of alternatives and mitigation measures are then undertaken, usually by expert consultants and often in partnership with outside experts from academia and NGOs. Then the findings are released for public consultation. The consultation responses and assessment findings are taken into account in deciding on the final plan. Through a process of open and rigorous assessment, the plan should then be not only more environmentally beneficial, but also have greater public support and legitimacy. Examples from Romania, Bulgaria and Spain (*Boxes 4 and 5*) illustrate the damage to Europe's most important protected areas that are likely to ensue where such plans are absent and/or do not take environmental considerations into proper account through the use of SEA.

Box 4 - The need for strategic planning for wind power development in Romania and Bulgaria

From 2006 Romania started to rapidly develop a wind energy industry. Much of this is concentrated in the relatively windy Dobrogea region on the Black Sea coast. As of the start of 2013 about 5650 wind turbines are planned or are already built in the Dobrogea region - one of the richest areas for biodiversity in Romania.

About 64% of Dobrogea is designated as Natura 2000 sites or other protected areas by national law. It is one of Europe's most important bird migration areas (on a migration route known as the 'Via Pontica'). It is the only wintering area in Romania for the critically endangered red-breasted goose *Branta ruficollis*, and is an important area for at least 20 bat species. About 30 habitats protected by the Habitats Directive have been described in Dobrogea.

Two priority habitats (ponto-sarmatic steppe and deciduous thickets) are likely to be directly affected by the turbines, reducing their area. Over 800 turbines have already been built or are planned in sensitive areas in Dobrogea, some of them near to the unique Danube Delta ecosystem, affecting areas for wintering red-breasted goose (e.g. Istria, Sacele), or areas important to other migrating species of geese, pelicans, raptors and storks. Some of the proposed wind farms in Dobrogea will affect breeding or migrating areas for raptor species (e.g. Babadag & Macin Mountains).

In the last three years NGOs (including SOR/BirdLife Romania) have lobbied central and local environmental authorities to put pressure on them to develop an SEA for wind energy development in Dobrogea, and to produce a bird sensitivity map. So far no concrete action has been taken. The main problem is that baseline data are missing: surveys are needed for birds, bats and habitats. In 2011, SOR started the necessary surveys on birds to develop a sensitivity map for the Dobrogea region.

In Bulgaria, wind energy development started to expand rapidly from 2003 onwards. Similar to Romania, the sites with the best wind resource were concentrated in the Dobrudzha Black Sea coast region, which also contains a large number of areas subsequently designated as Natura 2000 sites following accession into the EU in 2007. One of the key sites is the Kaliakra peninsular, identified as an Area of Special Conservation Interest by the Bern Convention and designated as a Special Protection Area under the EU Birds Directive, but subject to unplanned and poorly regulated wind energy and other development.

Kaliakra is within the core red-breasted goose wintering feeding area and a stop-over for migrating soaring birds in adverse wind conditions. Following a complaint by BSPB (BirdLife Bulgaria), the Bern Standing Committee opened a case file 'Windfarms in Balchik and Kaliakra – Via Pontica' in 2006 and following a mission in 2007 adopted Resolution 130 (2007), asking the Bulgarian government to address threats from wind energy development to migrating and wintering birds. Subsequent to the consent of Smin wind farm near to the key red-breasted goose roosting site of Durankulak Lake in northern Dobrudzha in 2012, the African-Eurasian Waterbird Agreement (AEWA) of the Convention on Migratory Species opened an Implementation Review Process case file in 2012. The conflicts between wind energy and nature conservation policy in Bulgaria could have been avoided with strategic planning and proper impact assessment of developments. As stated in *Section 2.2.1.1* above, the Bulgarian government have now put measures in place to stop all further wind energy development in the Dobrudzha region, but this leaves intact a 'toxic legacy' of damaging operational, consented and in-process projects that still need to be remedied.

The experience with wind energy development in Spain illustrates the problems that can arise when authorities allow rapid and largely unplanned investment to go ahead. The first few wind farms were evaluated as individual projects, but within a few years the avalanche of projects being presented forced the autonomous regions to call a halt to new projects whilst they prepared wind energy plans. Whilst in some cases these plans have been produced at regional level, in others such as Andalusia or Castilla & León they have been produced for each province.

The EU Strategic Environmental Assessment Directive (2001/42/EC) requires authorities developing plans in a range of sectors, including energy, to take environmental considerations into account through a process of assessment and consultation. In Spain, only two wind energy plans have been subjected to this type of evaluation: the regional government of Castilla-La Mancha conducted an SEA of its 'Wind Energy Plan to 2014', and the national Ministry for the Environment has carried out an SEA for offshore wind farm developments. In each case, the plan includes zoning which identifies compatibility of wind energy development with environmental conservation in certain areas, as well as identifying those zones most appropriate for development.

The failure to carry out SEA of wind energy plans elsewhere has in many cases meant that they have been prepared simply in terms of the distribution of the wind resource, without taking into account any environmental concerns. This is the case, for example, in the autonomous community of Valencia where the Wind Energy Plan was based almost exclusively on an evaluation of the wind resource carried out by one of the leading electricity companies in Spain, which was clearly interested in installing wind energy developments in the region. The European Commission is investigating this plan given that the areas identified as having potential for wind farm development overlap with the expansions of SPAs proposed by the regional government.

The failure to carry out SEA, far from accelerating wind farm development, can result in lengthy delay, as has been the case in Catalonia, where the Supreme Court of Justice has halted the planning of wind farms in priority zones for wind energy development because of the lack of environmental evaluation. A similar situation exists in Cantabria, where complaints have been registered in the courts because the wind energy plan was approved without being submitted to SEA, thereby failing to comply with Directive 2001/42/EC and the Aarhus Convention.

Box 5 - Failing to take the environment into account: The example of Spanish regional government planning for wind power

The case of Extremadura Region in Spain provides a vivid illustration of the grave deficiencies detected by SEO/BirdLife in the environmental evaluation of wind farms in Spain. In December 2006, the regional government announced in its Official Bulletin that 116 formal requests had been received to install wind farms in Extremadura (1,952 wind turbines totalling 3,670 MW) putting an end to the previous moratorium on wind energy development in this autonomous region. The number of projects, their geographical distribution, and the administrative arrangements for considering the applications for development consent make it abundantly clear that it was a wind energy plan in all but name, and, as such, should have been submitted to SEA prior to the subsequent EIA of individual projects.

Access to information provisions for the public were seriously deficient: the 116 projects were made publicly available over the Christmas/New Year holiday period in only one location (Mérida), during the mornings only, with a limit of seven people allowed to inspect the documentation at any one time and without the possibility of making any copies of the information presented. Furthermore, there was no additional publicity given to the fact that these 116 projects were available for public consultation, not even in the affected municipalities. The regional government had had detailed information on the projects, and their corresponding EIAs, since June 2006.

Of the 116 projects proposed, 16 had at least part of their area within an SPA and 11 within a SAC. Furthermore, 82 projects were sited within 10 km of Natura 2000 sites declared for birds or bats, and thus potentially could adversely affect the conservation objectives of these sites. However, not one of these projects was evaluated in terms of its impact on Natura 2000 sites and no less damaging alternatives were considered. Projects were proposed in sites as important as the Sierra de San Pedro SPA, with the highest density of Iberian imperial eagle *Aquila adalberti* in the world. Whilst 70 of the projects were proposed within IBAs, in not a single case was there any detailed evaluation of possible impacts on the IBA's ornithological values.

Other serious deficiencies in the evaluation of these wind farms (including clear infringements of EU law) detected by SEO/BirdLife include:

- Lack of proper consideration of project alternatives;
- Failure to consider cumulative effects of the projects proposed;
- Insufficient consultation with the nature conservation authorities;
- Inadequate inventories of fauna with failure to identify species especially vulnerable to wind farms or protected or endangered species; and
- Failure to consider the barrier effects of wind farms for birds and bats.

There are some general principles that should, and should not be followed when undertaking SEA for wind energy:

Regulators should:

- Approach SEA as an opportunity to learn, improve plans and programmes and build support;

- Engage environmental authorities (including biodiversity experts) and stakeholders early and proactively to help define the scope of the SEA, to help steer the process and to assist with data and methodologies;
- Identify and assess genuinely alternative ways to achieve a plan's objectives, including a 'most environmentally beneficial' alternative;
- Assess alternatives against a meaningful baseline, including having access to adequate data on existing biodiversity;
- Use the process and findings to revise the plan so that environmental impacts are avoided, minimised or mitigated, resulting in no net loss of biodiversity; and
- Ensure proper assessment of cumulative impacts are undertaken.

However, regulators should not:

- Approach SEA as an administrative hurdle, cost burden or delay in securing consent for inflexible plans;
- Ignore advice received at the scoping stage, nor employ lawyers and consultants to define the legally safe minimum SEA effort;
- Define the objectives of a plan so narrowly that reasonable competing alternatives are excluded;
- Engineer the baseline and assessment of alternatives to justify consenting the preferred plan without changes;
- Use the process and findings to justify losses of biodiversity or failures to avoid, minimise or mitigate impacts; or
- Overlook cumulative impacts arising from plans - they will not be properly addressed in later EIAs.

Box 6 provides a positive example of SEA from Spain in regards to the development of offshore wind.

Box 6 - Offshore wind farm development in Spain

Spain is a European and world power in terms of installed onshore wind energy capacity. Furthermore, with almost 5,000 km of coastline, and a reliable coastal wind resource, it should also be in the top rank of countries for coastal offshore wind power capacity. However, a range of economic, commercial and licensing constraints have impeded offshore wind development in Spain. There are concerns that, despite an SEA process that was positive and ground-breaking in many respects, the lack of attention given to the designation of future marine SPAs will further delay progress in what has the potential to be a key area of wind energy growth.

In April 2009, following the associated SEA process, the Spanish government published its *Strategic Environmental Report of the Spanish Coast for the Installation of Marine Wind Farms*. In nature conservation terms the key output was a sensitivity map which, after taking into consideration numerous possible constraints, divided Spanish inshore coastal waters into three categories of sensitivity to wind farm development: suitable for development; suitable for development but with constraints; and unsuitable for development (but with some possibilities for certain types of project if the concerns raised in EIA process can be adequately resolved).

The SEA process was led by the Ministry for Industry, Trade and Tourism (promoter) and the Ministry for Environment, Marine and Rural Affairs (environmental authority). It involved wide consultation with the energy sector, the regional governments, industry groups such as fishing and shipping interests and interested parties in wider society including environmental NGOs. In nature conservation terms it took into account existing protected areas designated in the Natura 2000 network and other areas protected under Spanish legislation, as well as the known distributions of key protected marine species.

In general, the process and final product was well regarded, although regional and sectoral concerns remain. The principal concern from a nature conservation point of view – raised consistently by SEO/BirdLife Spain (and yet to be adequately addressed by the Spanish government) is the failure to take into account in the sensitivity

analysis the marine IBAs identified in a LIFE+ project and accepted as potential SPAs by the Ministry responsible. This hugely important project, innovative in nature and pioneering in its use of satellite and other technologies to identify the key areas most important for seabird conservation, proposed 42 marine IBAs (covering nearly 43,000 km²) for SPA designation in Spanish waters (Louzao *et al.*, 2009). It is clear that onshore wind energy development cannot be allowed to proceed until the existence of these areas is fully acknowledged in the sensitivity map produced by the Spanish Government.

2.2.2 Sensitivity Mapping

Wildlife ‘sensitivity maps’ record the locations and movements of species that are vulnerable to the impacts of specific types of infrastructure development, such as power lines or wind farms (e.g. Bright *et al.*, 2008). They can be developed at local, regional or national scales, and can be used in a variety of ways by developers, policy-makers, regulators and conservationists. This information can be valuable to financiers and developers when weighing up the planning risks associated with specific proposals or investment plans. In several countries, and many European regions and localities, sensitivity maps have been used in official locational guidance for developers, and to inform strategic spatial plans and associated strategic environmental assessments. Strategic plans and guidance then can be taken into account in regulations and planning procedures. Or they may simply provide information to developers, indicating broad areas in which ecological impacts are likely to be more or less significant. In some countries policy-makers encourage developers to locate wind farms in low risk areas, by varying the level or availability of subsidies. In at least one case, mapping of resources and constraints alongside mitigation costs enables prospective wind farm developers to identify area to avoid as well as those where the environmental impacts are smallest and the economic opportunities are greatest (Obermeyer *et al.*, 2013). Sensitivity mapping is one of the most valuable tools for ‘positive planning’ for renewable energy.

2.2.2.1 Principles and Usage of Sensitivity Maps in Policy Frameworks

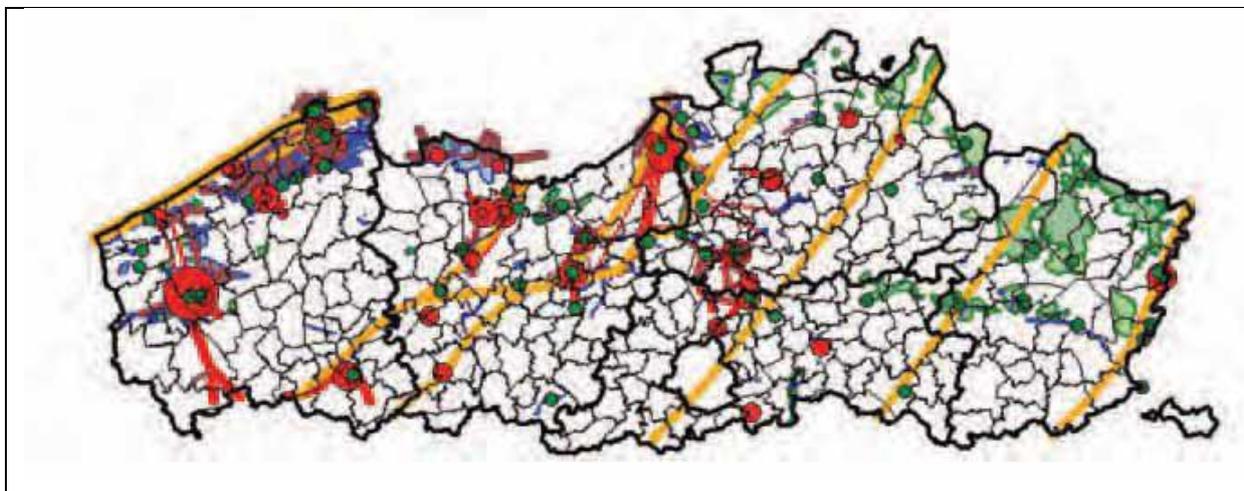
Land-use planning of some kind exists in many places, the key objective being the mediation of competing land-uses and priorities. Land-use plans set out mapped zones and/or policies regarding the suitability of the location of wind energy projects in terms of, among other things, likely impacts on important wildlife, plant species and habitats. This is one element of mapping the constraints that are relevant in steering the development of major new infrastructures. Other ‘layers’ in these maps may identify areas that are out of bounds for military reasons, for example, or areas set aside for some other competing use. The important step that needs to be taken is the routine use of bird and biodiversity ‘sensitivity maps’ as part of overall plans that steer investors to appropriate locations within broad zones.

Developers should have easy access to maps showing these sensitive areas and important features or locations, which indicate the ‘vulnerability’ to various types of development of the species and habitats found there. This will give them a good initial indication of whether refusal of development consent is likely on grounds of environmental impacts, or where there may be legal issues and/or high costs for creating compensatory habitat should they seek to develop those locations. Wildlife sensitivity maps can also be used in defining zones that are most suitable for wind energy development. The underlying data will not normally justify indication of exclusion zones, or replace the need to carry out any impact assessment. Rather, indication of sensitive areas assists developers by alerting them that there is likely to be a need for targeted, site-specific data collection and more detailed environmental assessments. The maps also assist strategic planning by indicating zones where there may be greater risks that a location is found to be unsuitable on environmental grounds. They may also allow planners to award ‘Green Certification’ to projects that actively avoid, minimise, or offset ecological impacts (Obermeyer *et al.*, 2013).

In France every region defines wind energy zones, and receipt of subsidies depends on locating within them. Wildlife sensitivity maps are also used in spatial planning in Scotland, Belgium (see *Figure 3*) and parts of Germany. In some countries, such as Wales and Scotland, zoning for wind power does not affect subsidy levels, but location within an area identified as suitable increases developers’ chances of obtaining planning permission. In many European countries BirdLife partners have developed sensitivity maps, but these have yet to be used routinely in spatial planning, such as in

Greece and the Netherlands. Other BirdLife partners are developing bird sensitivity maps, and/or providing expert assistance to national or regional authorities to do so. BirdWatch Ireland, for example, is in the process of producing a layered multi-species sensitivity map in conjunction with developers and regulators.

Figure 3: Bird Sensitivity Map for Flanders (Natuurpunt/BirdLife Belgium)



Box 7 - Bird sensitivity mapping in the UK

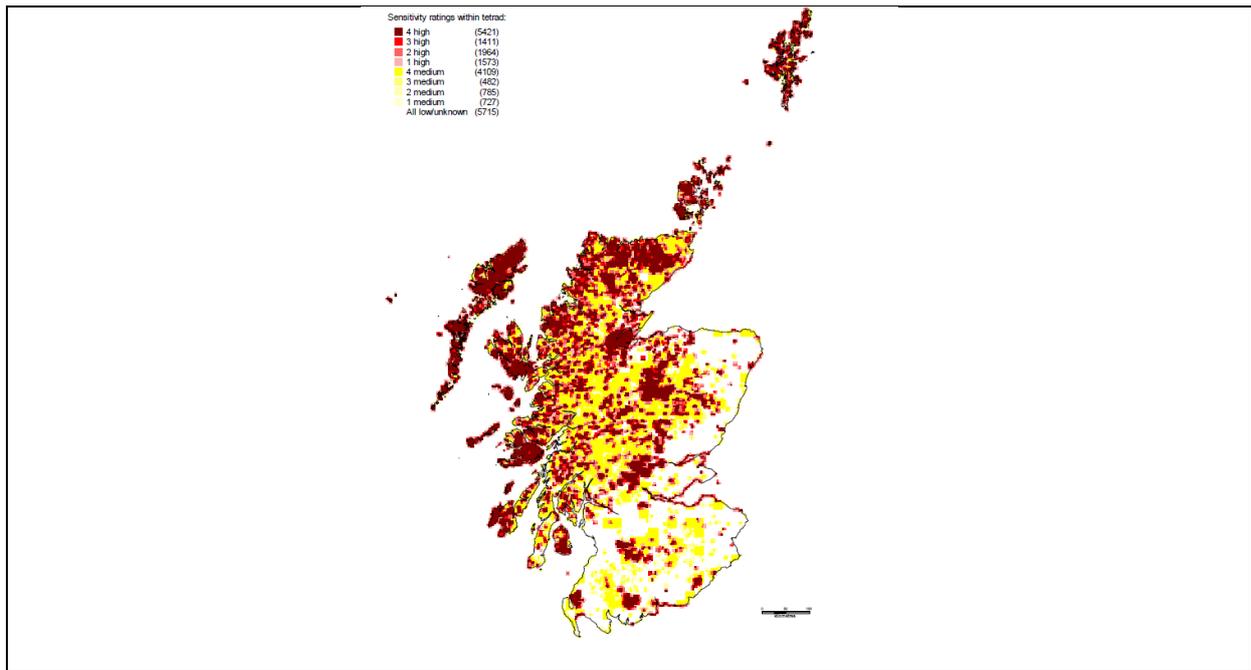
RSPB Scotland/BirdLife UK and Scottish Natural Heritage worked together to produce a Scottish 'Birds and wind farms' sensitivity map (Bright *et al.*, 2006; 2008). This was based on:

- Distributions of 18 species of bird considered to be sensitive to wind energy developments;
- Special Protection Areas, for congregational species groups notably non-breeding waterbirds and colonially breeding seabirds; and
- Other sites hosting nationally important populations of breeding waders and wintering waterfowl.

Reviews of literature on foraging ranges, collision risk and disturbance distances were conducted for each of the 18 species, to determine appropriate buffering distances. The findings were used to create a map of Scotland with each 1 km square classified as 'high', 'medium' or 'low/unknown' sensitivity. The map is intended to identify areas where it is considered there is more potential for impact of wind farms on sensitive bird species and stricter assessment of possible effects may be required, rather than to identify 'no go' areas.

Following completion of the map, RSPB Scotland wrote to Local Planning Authorities in Scotland inviting them to request detailed maps for their area, and also provided the maps to developers, consultants and other stakeholders. The Highland Council used the sensitivity ratings, alongside other constraint layers such as cost, visibility and designated sites, when identifying preferred areas for wind farm development in the Highland Renewable Energy Strategy.

Scottish Natural Heritage have produced their own location guidance for wind farms in Scotland, incorporating a number of different 'natural heritage sensitivities' and including the RSPB Scotland/SNH 'Birds and wind farms' sensitivity map. Following this, RSPB worked on a joint RSPB/Natural England project to create mapped and written guidance for England, using a similar approach (Bright *et al.* 2009).

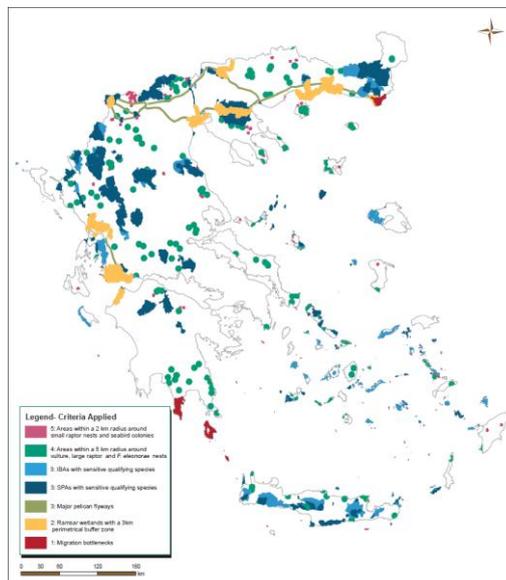


Box 8 - Bird sensitivity mapping in Greece

HOS/BirdLife Greece has identified and mapped those sites in Greece which are more sensitive to the presence of wind farms from an ornithological and biodiversity perspective (Dimalexis *et al.*, 2010). The best available ornithological information was compiled and processed cartographically, to indicate areas that are least suitable for wind farm development across the whole country. The aim is to provide the Greek administration and stakeholders with the information needed to protect critical habitats and the most vulnerable bird species.

The methodology employed is a stepwise process, applying five distinct criteria of equal importance to determine areas of high sensitivity to wind farm development. The purpose of this approach is to produce a final map product, composed from the five non-overlapping thematic criteria maps. The criteria used were:

- IBAs and SPAs that have been identified as migration-bottlenecks;
- Ramsar sites with a 3 km buffer zone around their limits;
- IBAs and SPAs with qualifying (trigger) species most threatened by wind farms, and major pelican flyways; and
- Certain species of small raptors and seabirds breeding at sites other than those covered by the criteria above, with a 2 km buffer zone around nests and colonies.



2.2.3 Site Selection Protocols

2.2.3.1 Natura 2000 Sites, the Emerald Network, other Protected Areas and Wind Energy Proposals

Healthy, biodiverse environments play a vital role in maintaining and increasing resilience to climate change, and reducing risk and vulnerability in ecosystems and human societies. In the European Union, Natura 2000 sites provide these healthy, biodiverse environments. The Natura 2000 network of sites protected under the EU Birds and Habitats Directives lies at the heart of Europe's efforts to protect its biodiversity. Natura 2000 sites are not 'fenced-off' protected areas. On the contrary, they are often dependent on sustainable human activities and land-use that have shaped them and maintained them over the years. The Natura 2000 network covers almost a fifth of the EU territory; over 25,000 sites where nature can exist in harmony with humans. The network is now almost complete on land, but there is still much work to do offshore (see *Box 3*).

Marine spatial planning and a robust Natura 2000 network (and national designations outside of the EU) will be vital for enabling biodiversity to adapt to climate change whilst allowing sustainable development and use of offshore resources.

The Birds and Habitats Directives represent an 'enlightened approach to dealing with environmental constraints, and one that is at the heart of sustainable development' (SDC, 2007). A key part of this is making sure the best areas for wildlife in Europe, Natura 2000 sites, are properly protected in the wider public interest, so that they continue to make their full contribution to securing the favourable conservation status of the habitats and species they conserve. For good reason, the Directives only allow these sites to be damaged in exceptional circumstances and require strict tests to be passed first (see *Section 2.4.3*). However, it is important to say that not all wind energy development will have adverse effects on Natura 2000 sites – which is why rigorous Appropriate Assessment processes need to be applied in each individual case; as mentioned before, impacts are site and location specific. However, when adverse effects cannot be ruled out, the tests, applied in a systematic, robust and transparent manner, can ensure decisions on whether to damage some of Europe's most important wildlife areas are taken in the genuine interests of society as a whole. Where this fails in sub-national decision-making, Member States may decide that it is necessary to go beyond the Directives' requirements, by banning certain types of development in Natura 2000 areas (*Box 9*).

Box 9 - The Italian reaction to inadequate application of the Habitats Directive tests

In Italy, ill-conceived or non-existent spatial planning has jeopardised many sites of great value for biodiversity. In the Puglia Region, hundreds of wind turbines have been developed within the Important Bird Area (IBA) Monti della Daunia, resulting in serious degradation of the site. The nearby Basilicata Region is the most important in Italy for red kite, and is home to over half of the 10-12 pairs of black stork *Ciconia nigra* breeding in Italy.

Unfortunately the Basilicata Regional Energy Plan pays very little attention to IBAs and Natura 2000 sites. A wind farm development near Campomaggiore consisting of seven 1.5 MW turbines has been recently completed. The towers are well within an Important Bird Area (IBA) and between three Natura 2000 sites, each classified as both SCI and SPA. Black kite *Milvus migrans*, black stork, Eurasian eagle owl *Bubo bubo*, lanner falcon *Falco biarmicus*, red kite and short-toed eagle *Circaetus gallicus* nest in the IBA; these are all species listed in Annex 1 of the Bird Directive, and all have 'unfavourable' overall pan-European conservation status (BirdLife International, 2004). Nevertheless the regional authorities decided that the project mentioned above was exempt from EIA and from 'appropriate assessment' under Article 6 of the Habitats Directive. The project was not even made public, so stakeholders had no chance to comment on it. On the wind farm site, a winter-roost hosting a stable population of about 100 Red Kites was present - not any more.

In November 2007, a decree named "*Minimum homogenous criteria for definition of conservation measures for SACs and SPAs*" was signed by the Italian Minister of Environment. This decree prohibits certain activities in Special Protection Areas, amongst others, it prohibits the construction of new large wind turbines. The decree was issued in response to the European Commission infringement procedure 2131 (2006), which points, amongst other things, to the lack of coherent conservation criteria for Natura 2000 sites. The focus is mainly on SPAs, but principles for future conservation measures for SACs are also laid out.

This measure was recently referred to the European Court of Justice by a wind energy company, based on the refusal of Apulia Region to authorise the location of wind turbines in "Alta Murgia National Park" SPA (and

SCI). The developer bringing the legal action had argued that European law required ‘appropriate assessment’ before authorisation could be refused, and that the Decree is therefore unlawful. The court concluded that the ban on locating wind turbines in SPAs does not contravene EU Directives on nature protection and promotion of renewable energy.

The European Environment Agency (EEA, 2009) calculated that the technical potential for onshore wind energy in Europe is over ten times total electricity consumption, and that excluding Natura 2000 and other protected areas would reduce this by just 13.7%. The same study estimated that the potential for economically competitive onshore and offshore wind energy in Europe by 2030 is over three times greater than total electricity consumption. It therefore follows, that sufficient suitable locations can be found for our energy needs to be met using renewables and without creating risks for biodiversity in protected areas or in the wider countryside. However, this cannot be left to chance: sufficient suitable locations for development need to be identified and developers must be steered towards them.

Within the wider area covered by the Bern Convention, the Emerald Network is made up of Areas of Special Conservation Interest (ASCI) which are assessed at a bio-geographical level and adopted in order to ensure the survival of species covered by the Convention. Once adopted these sites need to be designated and managed at national level (Natura 2000 effectively substitutes for the Emerald Network within the EU). The Emerald Network should be completed by 2020 in contracting party states.

Developers and investors need to take into account in their site selection processes that although in some circumstances wind energy development will be acceptable in and around designated and proposed Natura 2000 and ASCI sites (and other national designations), the project risks and costs are likely to be much higher. The increased project delivery time and the rigorous impact assessment processes that will be needed, as well as the high potential need for mitigation are all likely to add to project costs, and there is a higher possibility of consent refusal on ecological grounds. A precautionary avoidance approach to protected areas, and key biodiversity sites will help ensure impacts are minimised and developments are located in appropriate areas.

2.2.3.2 Presence of Breeding Sites of Sensitive Species

As well as taking into account the presence of protected areas when undertaking site selection, developers also need to take into account the presence of breeding birds of sensitive species, with particular reference to raptors onshore and seabirds offshore. Conservation stakeholders will often be able to inform developers of known breeding sites of protected species. By not placing turbines within certain buffer distances of known nests, developers will reduce the potential for impacts from disturbance, and also from collision with foraging birds, or juveniles. Guidance on suitable buffer distances can be found in the literature (Hötker *et al.*, 2006; Ruddock & Whitfield, 2007; Bright *et al.*, 2009 + literature specific to particular species). Suggested buffer distances are species specific, and can vary from 100’s of metres to several kilometres (in the case of some eagle spp.). In some instances where the precise location of sensitive breeding species is not known before EIA baseline survey, micro-siting (see below) within the project area can reduce likely impacts. Several German Lander apply buffer distances in decision-making on wind farms – notably for red kite. Active avoidance by wind farm developers of the breeding sites of protected species in the site selection process will reduce the risk of conflict and is likely to reduce project risk and uncertainty.

2.2.3.3 Micro-siting

Micro-siting is the fine scale movement of turbines within a design layout, typically of less than 100 m (SNH, 2009b). Generally such design changes are made due to landscape features, underlying substrates and geology, as well as access. However, even small changes alter the potential impact of the wind farm on ornithological interests.

Underlying topography can influence the location of flying raptors (Madders & Whitfield, 2006). For example, golden eagles (McLeod *et al.*, 2002), will fly disproportionately more over convex topographical features such as ridges. Such preference for convex features has also been reported at Altamont Pass for red-tailed hawk and American kestrel (Smallwood & Neher, 2004). The same

study noted that all three species flew over the windward aspects of ridges more than the leeward aspects, and would change sides if the wind direction changed. Satellite telemetry studies in the US (Katzner *et al.*, 2012) have shown that golden eagles, both on migration and making local flights, will fly at lower altitudes, and therefore be at greater risk of collision, over steep slopes and cliffs. A study of 20 wind farms, and a further 33 potential wind farms in Tarifa, Spain also found clear evidence that topography was an important factor in determining the potential for collisions (Ferrer *et al.*, 2012). The study concluded that individual turbine location, via micro-siting, was crucial to minimising bird mortality.

The Foote Creek Wind Farm in Wyoming, is located on a prominent flat topped mountain with steep slopes on the east and west sides. Initial ornithological surveys indicated a serious threat to the resident raptor species (Strickland *et al.*, 1998). An 80 m setback of turbines was proposed to reduce the risk of impacts, and the operator instigated a 50 m setback from the ridge edge. Subsequent monitoring studies have shown low raptor fatality rates at the site (Strickland *et al.*, 2001). A similar turbine setback has also been instigated at another Wyoming wind farm: White Mountain, (Jakle, 2012).

Many regular movements of waders and wildfowl, for example between roost sites and foraging areas, are highly predictable, and the micro-siting of turbines away from the line of such routes can substantially reduce predicted collision rates and minimise the potential for barrier effects.

While micro-siting is mainly considered to have an impact on structural and visual elements of a wind farm, it therefore must also be considered in the context of ornithological impacts, and the potential to substantially increase, or decrease these.

2.3 Environmental Impact Assessment

2.3.1 Principles of Environmental Impact Assessment

Impact Assessment processes can ensure existing biodiversity is protected and identify opportunities to enhancement and meet relevant targets. They do this by:

- Enabling stakeholder participation in formulating proposals;
- Identifying the likely negative effects of proposals on biodiversity;
- Evaluating how serious these effects are likely to be, including cumulative effects;
- Considering less environmentally damaging alternatives to the policy, plan, programme or project;
- Identifying any likely positive effects or opportunities to address biodiversity targets, e.g. through habitat creation;
- Identifying how any negative effects can be avoided or reduced; and
- Ensuring that negative effects are mitigated and that the implementation of a policy, plan, programme or project is monitored.

EIA helps ensure large wind energy projects and developments in sensitive areas do not go ahead without proper consideration of environmental impacts. It enables the concerned public and stakeholders to find out about such developments and engage with the relevant planning process. In this way it often leads to better projects with less overall impact on nature and the environment, or prevents the very worst projects and severest impacts on biodiversity from going ahead.

Globally there have been a number of initiatives specifically on biodiversity and impact assessment, for example:

- Adoption of both EIA and SEA guidance by the Convention on Biological Diversity (CBD), most recently in 2006 (CBD, 2006);
- Adoption of EIA and SEA guidance by the Ramsar Convention, most recently in 2008;

- Development of principles on ‘biodiversity-inclusive’ impact assessment by the Biodiversity Section of the International Association for Impact Assessment (IAIA) in 2005;
- The IAIA Capacity Building for Biodiversity and Impact Assessment (CBBIA) project, in which the CBD and Ramsar Conventions were closely involved. The CBBIA outputs include training manuals and EIA/SEA guidance; and
- An increasing interest in including economic valuations and information about ‘ecosystem services’ into impact assessments.

Biodiversity impacts are covered in EIA and SEA, but are not always accorded adequate priority, and the guidelines above are not well applied in many cases. As a result the potential of environmental assessments to help protect biodiversity is not always realised. Common weaknesses are:

- Not all policies, plans, programmes and projects affecting biodiversity are subject to impact assessment;
- Transparency and opportunities for public participation are often inadequate;
- Provision of baseline information and assessments of likely impacts are often poor quality, where these are not carried out in an impartial and rigorous way;
- Impact assessments often concentrate on limited components of biodiversity, such as designated sites, rather than looking at all levels/facets of biodiversity that could be impacted (e.g. ecosystems, habitats, species, connectivity and ecosystem services);
- Impact assessments often fail to include economic information relating to changes in ecosystem services;
- Assessments do not assess alternative proposals in order to identify a most environmentally beneficial option;
- The ‘no net loss’ and ‘mitigation hierarchy’ principles are not implemented adequately;
- Post-decision monitoring and enforcement of mitigation measures are often inadequate;
- Appropriate methodologies have not been used to generate scientifically robust information; and
- Practitioners are not trained appropriately in assessment methodologies or in species identification.

Timeframes for assessment/monitoring have not generally been long enough to generate accurate results. In the European Union, ‘Appropriate Assessment’ under the Habitats Directive is a key tool for avoiding impacts on Natura 2000 sites. The broader environmental assessment system is a powerful tool for informing decision-making about wider impacts. EIA and SEA have particularly important roles in relation to impacts in the wider countryside outside the Natura 2000 network, at sea and outside the EU, and in addressing the implications of climate change for biodiversity. These assessments provide established, consistent and systematic mechanisms for integrating biodiversity considerations into decision-making processes for wind energy development, at all levels.

In many EU Member States the ‘appropriate assessment’ required to satisfy the strict tests are conducted as part of an Environmental Impact Assessment (EIA). In others, these are treated as two separate processes. EIA applies to large projects that are likely to have significant impacts on the environment. Like SEA, it is a publicly accountable process, relying on rigorous scientific assessment work, transparency and public participation.

This section of the report discusses best practice for Impact Assessments for wind energy projects. This includes their content and procedural elements, and methodologies for baseline data collection and impact assessment.

2.3.1.1 Screening and Scoping

Care needs to be taken by regulators when screening wind energy developments to ensure that impacts on birds and biodiversity are assessed through EIA where potential impacts could occur. First

and foremost the scale of the wind farm and whether there is potential for significant impacts both alone and in-combination (cumulatively) with other projects need to be gauged. The cumulative impacts of multiple projects should not be ignored if regulators are applying thresholds when considering whether projects need EIA. ‘Salami slicing’, is a tactic of proposing a number of smaller projects under screening thresholds, which individually are unlikely to have significant impacts, but together may well do so. This tactic must be recognised by regulators and EIA undertaken for projects in this situation. Ideally, regulators should undertake a screening process for all wind energy development on the basis purely of the likelihood of significant impacts on nature conservation interests arising from the project without the use of thresholds. Additional aspects that need to be taken into account in the screening process include the environmental sensitivity of the area likely to be affected by the wind farm, the species likely to be vulnerable to impacts by the development and lastly the likely extent of the impacts of the wind farm, their magnitude, probability, duration, frequency and reversibility require initial assessment.

With regards to scoping, regulators and developers should consult widely (including relevant government advisor and NGO stakeholders) on what the likely receptors of effects from a wind energy proposal are likely to be. Consideration needs to be given to the range of sites/species affected, as well as types of impact (e.g. see Langston, 2010). The scoping process should ultimately lead to:

- Agreement on a list of key species likely to be at risk;
- Identification of key sites and their interest features (species) which may be affected;
- Definition of reference populations and the geographical area of impact; and
- Agreement on methods of data collection and analysis, and impact assessment.

Care needs to be taken to differentiate between the needs of assessment processes under EIA/SEA and (within the EU) Appropriate Assessment under the Habitats Directive. The scope of these assessment processes will differ, although there will be overlaps, so synergies on baseline data gathering and some assessment methodologies can be sought. Guidance on the Article 6 tests of the Habitats Directive can be found in European Commission’s guidance document (European Commission, 2010).

For further discussion of how to take into account Cumulative Impacts in screening and scoping please refer to *Section 2.3.3.1*.

2.3.1.2 The Mitigation Hierarchy

Despite the premise in the international biodiversity-related Conventions and in the EU 2020 target that further loss of biodiversity is unacceptable, biodiversity is currently in crisis as losses continue. Biodiversity must be conserved to ensure it continues to provide services, values and benefits for current and future generations. Prioritising according to the following approach will help achieve no net loss of biodiversity and contribute to delivery of the 2020 biodiversity target:

- Avoid irreversible losses of biodiversity;
- Seek alternative solutions that minimise biodiversity losses;
- Use mitigation to restore biodiversity resources; and
- Compensate for unavoidable loss by providing biodiversity offsets of at least equivalent biodiversity value.

This approach is sometimes referred to as application of the ‘mitigation hierarchy’ and/or ‘positive planning for biodiversity’. It helps achieve no net loss by ensuring that priorities and targets for biodiversity at international, national, regional and local level are respected, and that policies, plans, programmes and projects routinely make a positive contribution to achieving these - for example ensuring that common biodiversity is kept common, habitats and species in Favourable Conservation Status (FCS) remain in good status, and helping restore habitats/species to FCS.

In addition to the mitigation hierarchy above, wind farm developers can as part of their Corporate Social Responsibility choose to implement ecological ‘enhancements’. Enhancements are

improvements that go beyond measures required to mitigate or compensate for damage. These may be within or adjacent to sites where wind energy developments are developed, adding biodiversity benefits to the facilities' green credentials. For example, at Whitelee in Scotland one wind farm developer is re-establishing heathland and blanket bog over a very large area (*Box 10*).

Box 10 - Habitat enhancement at Whitelee wind farm, Scotland

Whitelee wind farm, near Glasgow in Scotland, is a good example of a wind farm development contributing to habitat enhancement. Whilst overall the site is not particularly sensitive for birds RSPB Scotland/BirdLife UK had some concerns with the original proposal relating to impacts on black grouse *Tetrao tetrix*. Minor amendments to the layout allowed these to be allayed and the proposal was progressed. The size of the wind farm site (more than 5,000 ha) means that there are opportunities to undertake large-scale habitat restoration and enhancement. These include re-establishing 900 ha of heathland and blanket bog through the clearance of conifer plantations, drain blocking and the continued management of a mosaic habitat to benefit black grouse. Liaison between the developer, ScottishPower Renewables, and RSPB Scotland was effective and led to the NGO being represented on the Habitat Management Group, which oversees ongoing habitat management to benefit wildlife.

Because of these positive benefits for wildlife and renewable energy generation, RSPB Scotland supported ScottishPower Renewables' application to extend the wind farm by a further 75 turbines, giving it the capacity to power nearly 300,000 homes. The Whitelee visitor centre, which opened in 2009, now attracts over 9,000 visitors a month, and includes an exhibition about the construction of the wind farm and the ongoing habitat management work conducted on site.

There is potential to carry out enhancement measures on land which is under the direct or indirect control of the developer, and which may be inside the project boundary. Onshore wind is particularly suited to an 'enhancement' approach, for the following reasons:

1. Most major onshore wind energy projects are located in either upland or coastal locations, in the remote countryside. These are also the areas which are most likely to contain substantive wildlife resources. They thus have the most potential to be the recipients of enhancement measures because the enhancement builds upon existing resources.

2. The physical footprint of such projects is relatively small, compared with the size of the project site/wind farm, which means that there is great potential to carry out enhancement measures on land which is under the direct or indirect control of the developer, and which may well be actually inside the 'development boundary'.

Measures such as control of grazing regimes, control of hydrology and conifer (or other exotic tree-species) removal can improve, restore or create upland or coastal habitats of acknowledged biodiversity importance. Of course, care should be taken that enhancement measures should not be proposed that would potentially increase impacts on sensitive species – for example provision of prey habitat for raptors in the vicinity of turbines.

Offsite ecological enhancements are also a possibility. Developers of many kinds of infrastructure sometimes provide incentives to local communities. This is sometimes in the form of funding for amenities such as sports facilities or school equipment. Creating new wildlife-rich areas, or helping improve existing ones, is an excellent way to benefit communities. Access to green space that is rich in wildlife has been found to be good for people's physical and mental well-being (Diaz *et al.*, 2006; Barton & Pretty, 2010), and provides local schools with opportunities for educational experiences.

Further information on potential mitigation measures and enhancement is provided in *Section 2.3.4*. Developers and Regulators should be mindful that avoidance through appropriate site selection is nearly always the most appropriate and easiest option to avoid impacts on sensitive bird populations.

2.3.1.3 Focus on Key Species and Habitats

Impact assessments should focus on the key species and habitats likely to be impacted by the wind energy development. This can be done through effective scoping that identifies which species and habitats should be the focus of baseline monitoring and subsequent impact assessment. This is

very important to provide focus for the EIA and to get away from wind energy Environmental Impact Statements ('EISs') that simply list everything that is present in and around the site, or which spend much of their (often voluminous) length describing and analysing *de-minimus* effects on species/habitats of little conservation concern.

Focusing on key species and habitats potentially shortens EISs, signposts decision-makers to consideration of the key issues, and allows often limited resources to be concentrated on providing quality baseline information and assessment on those impact receptors of key relevance to the project development and decision-making process.

Guidance documents on EIA provide advice on how to frame these judgements and should be used when applying this approach (European Commission, 2001; IEEM, 2006). The EIA must use methodologies that appropriately assess the species and habitats present, and be carried out over a timeframe which guarantees temporal/seasonal issues are accounted for. Developers should consult statutory nature conservation agencies, and other sources of expertise (such as NGOs) before determining a final list of focal species and habitats.

2.3.2 Risk Assessment and Allocation of Risk: Determining Significance

The significance of an impact is a key consideration when deciding on whether consents should be given for a wind energy project, taking into account what mitigation could be provided to reduce or remove those impacts, and whether compensation is needed if the need for the project is deemed to outweigh any damage it does that cannot be avoided/mitigated.

The significance of a particular impact (i.e. whether or not there will be population level effects) will vary, depending on the circumstances of the particular case. Factors which may influence the relative significance include:

- Species involved (reproduction strategy, lifespan, etc.);
- Population size, distribution and status;
- Magnitude of impact;
- Probability of impact;
- Type of impact;
- Extent;
- Duration;
- Intensity;
- Timing; and
- Probability.

It is important that all of these attributes are considered in assessing the significance of an impact and described as fully as possible in the EIA. The predicted impacts (or observed effects) of a particular wind farm (or any other kind of development) may or may not be significant and lead to potential adverse effects, indeed the same impacts in different locations may have different consequences. It is also important that all relevant impacts of an individual project are considered, such as impacts during construction, operation and decommissioning. In addition, significance of an effect cannot be judged in isolation, on an individual project basis, but must be considered in combination with other projects and effectors. *Section 2.3.3* considers cumulative effects in more detail.

Clearly there is a distinction to be made between effects of a temporary or permanent nature. Any predicted impacts also need to be put into context at a local, regional, national and/or international spatial scale. The precautionary principle should be strongly adhered to in all cases where detailed information on the specific responses of particular species is not fully available or understood. Where the predicted impacts are likely to be significant, they need to be compared with the background mortality rate of the reference population at the appropriate scale (e.g. colony, region, national, international flyway or biogeographic populations) to enable life history parameters and ecology to be accounted for when determining whether or not there is likely to be a population level effect. Detailed population modelling methods may be required to determine the effects of predicted impacts (see *Section 2.3.6.7*).

During the breeding season the basic unit for a reference population is likely to be the colony. However, a single development site (or group of sites) might contain birds originating from a number of colonies, and a single colony might be affected by developments at a number of sites. Usually the search area is based on the likely foraging area of the species in question, which is derived from available literature sources, such as Thaxter *et al.* (2012). In terms of assessing the scope for impacts of an individual project, all colonies which fall within the mean maximum foraging distance for a species are often considered to be at potential risk. However, note that in at least one case, species present in the proposal area were at the maximum extent of their reported foraging range. It is important to note that advances in tracking technology are revising foraging ranges (often upwards) for several species, illustrating just how limited existing information has been. So, whilst maximum foraging range may be considered potentially indicative of food shortage, this has to be weighed against other information. In terms of cumulative assessments all sites which are within at least the mean maximum foraging range should be included and available evidence used to scope out sites as appropriate. The most precautionary approach to assess potential effects at a colony level is to compare the total cumulative mortality with the background mortality at each colony sequentially. However, it is commonly accepted that in most cases this is likely to overestimate the risk particularly for colonies which are at a considerable distance from the site. As a consequence, various methods are under development for calculating the extent of the reference population and apportioning risk between different colonies (e.g. Joint Nature Conservation Council, Natural England, Scottish Natural Heritage unpublished & in prep. guidance). Often such methods include weighting factors to account for colony size (as a proportion of regional population) and distance from the site.

Depending on the species and reference population, impacts may need to be considered at different population scales at different times of year. For example, outside the breeding season the reference population is likely to be much larger, and might be based on a regional population or an even larger scale, depending on the ecology and behaviour of the species in question. In such circumstances the total impact on the population should be the summation of risk for each period of the year.

Controls associated with statutorily protected sites (such as Natura 2000 sites in the European Union), may dictate the significance thresholds of impacts when it comes to decision-making (e.g. European Commission, 2010). In all cases where there is uncertainty about the significance of an impact, the precautionary principle should be applied during decision-making. All analyses should be presented as clearly as possible, identifying data collection protocols, methods of data analysis as well as any parameters used and assumptions made. Developers and regulators should take into account guidance on how to determine significance (see, for example, European Commission, 2001; 2010; IEEM, 2006) when undertaking assessments and considering their implications.

2.3.3 Cumulative Impact Assessment

The assessment of cumulative effects should be an essential component of the impact assessment of wind farm proposals. Unfortunately, this aspect of risk assessment is often inadequately covered (Masden *et al.*, 2009a). Cumulative effects may arise from the development of multiple wind farms or from individual wind farms in conjunction with other types of development. Impacts may operate at different spatial scales, from an individual breeding population or colony level to the bio-geographic population or flyway scale. The potential cumulative effects of multiple wind energy installations are frequently of concern, particularly in relation to local (occasionally national) population level effects through disturbance/displacement, collision mortality and barrier effects.

Even where predicted impacts at a particular site are low, this does not necessarily mean that the cumulative impacts will be insignificant, particularly in landscapes with multiple small wind farms or where there are a few wind farms comprising a large number of turbines. For example, even relatively small increases in the mortality rates of breeding adults, or decline in productivity, could be significant for populations of some bird species, especially those which are long-lived with generally low annual productivity and long adolescence, notably seabirds, waders, wildfowl, raptors and soaring birds. This is particularly the case for species which are already rare or facing a number of other pressures from environmental changes and/or anthropogenic impacts. In such cases, there could be significant effects

at the population level (locally, regionally or, in the case of rare and restricted species, nationally or internationally) (Drewitt & Langston, 2006).

In particular, migratory species might face significant cumulative impacts when developments are planned along migration routes. It is possible that a bird population might face cumulative impacts of different classes, during different phases of the life-cycle, for example, direct habitat loss and displacement from breeding and/or wintering grounds, in addition to collision risk and/or barrier effects during migration. In addition to direct mortality, sub-lethal effects (such as loss of body condition, due to displacement, barrier effects or loss of habitat) are more insidious than direct mortality and there may be a delay before any population-level impact is detected. 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) (see *Section 2.2.1.3*). The cumulative indirect effects of large-scale wind farms are not well understood, for example the effects on hydrology or micro-climates and habitat fragmentation.

2.3.3.1 Best practice in Cumulative Impact Assessment

The principles of CIA are very similar to those of EIA described above, and rely on the step-wise process of screening, scoping and the assessment of impacts and consequences.

1. Screening: The following CIA issues should be taken into account:

- Firstly, whether there is potential for cumulative effects with other projects;
- Secondly, the environmental sensitivity of the area likely to be affected by the wind farm, and species involved; and
- Thirdly, the extent of the impacts of the wind farm, their magnitude, probability, duration, frequency and reversibility.

2. Scope: A cumulative impact assessment should consider all other plans or projects within the area surrounding the proposed wind farm site and within the relevant geographic scale for the target species. It should include all projects currently seeking approval from the planning authorities as well as those that have received planning permission (King *et al.*, 2009). Projects which have already been completed, may be considered to impact upon the baseline and therefore be excluded from the CIA, however, if their full impact is yet to be exerted it may be necessary to include them. The issue of baseline creep (i.e. un-mitigated impacts slowly accruing on the baseline of the population in question without ever reaching a threshold of significance), is a real concern. If there are any other types of projects which have been planned or are under development in the area (for example forestry operations, gravel extraction or industrial development), 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. The geographical scale over which cumulative effects must be considered should cover a sufficiently large area to capture any cumulative effects that may arise with the project under assessment, including trans-boundary (international) aspects.

3. Assessment of extent of impacts: The effects of local changes in abundance and distribution of birds caused by wind farm construction may lead to changes in demographic processes and could consequently lead to population level impacts. This necessitates a population level or flyway approach, including consideration of cumulative impacts at these scales. Guidance recommends that the cumulative effects of collision risk and displacement should be assessed by summing the impacts from each component project (King *et al.*, 2009), however, it should be born in mind that cumulative impacts might increase in a non-linear manner, and so summing impacts might underestimate (or in certain circumstances overestimate) overall effects.

4. Assessment of effects (significance of impacts): Where collision mortality or displacement is likely to be significant the predicted impacts need to be compared against the background mortality rate of the reference population at the appropriate scale (e.g. colony, region, national, international flyway or biogeographic populations) to enable its life history parameters and ecology to be accounted for when determining if there is likely to be a population level effect. Detailed population modelling may be required to determine the effects of predicted impacts (see *Section 2.3.6.7*).

2.3.4 Mitigation Measures and Enhancement

One of the main purposes of the development of a renewable energy industry is to help to reduce carbon emissions and thereby limit climate change. However, healthy ecosystems will also be essential to enable society and nature to survive the warming that is already locked into the system, and which we cannot avoid. It is therefore important that renewable energy technologies such as wind power are deployed in such a way as to minimise potential impacts, and where such impacts are unavoidable the industry and regulators ensure that adequate mitigation and/or offsets are undertaken to minimise negative effects. Natural and semi-natural habitats have undergone unprecedented destruction, modification and alteration over the past few decades (Hoekstra *et al.*, 2005). The development of renewable energy technologies and their installation offer the opportunity, through diversification of rural incomes, to reduce the intensity of land use, and could result in a net gain in terms of wildlife and habitats, and so it is important that the industry does not ignore this opportunity.

The mitigation hierarchy (see *Section 2.3.1.2*) should be followed with one golden rule - adverse impacts should be avoided wherever possible, preferably by siting wind farms away from vulnerable bird populations. If adverse impacts cannot be avoided, then suitable mitigation measures should be employed to reduce them. Finally, significant adverse impacts that cannot be mitigated require compensation (offsets), if the project is to proceed.

2.3.4.1 Mitigation

Where detrimental impacts on species or habitats have been identified in the EIA, or there is considered to be a significant risk of such impacts, mitigation measures to avoid, reduce or remedy the impacts should be implemented. Clearly the costs of any mitigation should be proportional to the size of the potential impact, but it is a basic test of economic sustainability – if the cost of mitigation outweighs the economic benefits of a particular development then it is highly likely that it is in the wrong location in both an ecological and economic sense. Mapping of mitigation costs alongside resources and constraints (e.g. see Obermeyer *et al.*, 2013), has potential utility in identifying areas where mitigation is likely to be required and where costs are likely to outweigh benefits.

Mitigation options can be divided into the following main areas:

Modification of site design and layout

There are a variety of ways that the design of wind farm sites and their location in the landscape may be modified to mitigate for the potential impacts arising from the development.

Design of the site: In terms of orientation, spacing and location of turbines (micro-siting – see *Section 2.2.3.3*), number of turbines.

Design of infrastructure: Access roads/tracks, hard-standing, sub-stations, scour protection (offshore); avoiding the use of structures with guy lines are areas where sensitive design can play an important role.

Layout at a landscape scale: It is believed that the consideration of the cumulative impacts of projects in wind farm design could alleviate potential barrier effects on birds along or across migratory corridors. For example, by orientating turbine rows in the same direction as the main transit routes, organising turbines in discrete groups rather than filling the whole landscape or leaving transit corridors between groups of turbines. Avian movement models may be used in the future to provide insights into how to reduce impacts of wind farm developments (Masden *et al.*, 2012; Schaub, 2012).

Power lines: Should be buried (undergrounding) where possible (subject to habitat sensitivities and in accordance with existing best practice guidelines for underground cable installation); where distances to grid connections make this a prohibitively costly option any above ground grid connections should follow available best practice guidelines to minimise bird mortality (e.g. Haas *et al.*, 2005; Prinsen *et al.*, 2011b).

Repowering: The replacement of existing turbines with fewer larger ones, has been shown to significantly reduce collision risk and/or displacement whilst maintaining or increasing generation capacity (Krijgsveld *et al.*, 2009; Smallwood & Karas, 2009).

Modification of turbine design and operation

Turbine design: Features such as tower type (e.g. lattice type vs. tubular designs), hub height, and turbine size (blade length) can all be modified to reduce potential impacts. Careful design and removal of features likely to attract bird use (such as perches or potential nest sites) can also reduce the risk of collision.

Remodelling the site: In cases where significant mortality has been detected around particular turbines, it may be appropriate to consider their removal (deletion/decommissioning), or moving turbines to more benign locations within the wind farm.

Minimising non-operational periods: Through regular maintenance and the removal of broken or obsolete turbines the perching of raptors can be reduced, which has been shown to reduce the risk of collision (Smallwood *et al.*, 2009).

Cut in speeds: There is evidence that a higher proportion of bird activity occurs in weak wind conditions, and that certain species (such as soaring birds) are at greater risk of collision in such conditions (e.g. de Lucas *et al.*, 2008; Farfán *et al.*, 2009). Therefore, raising the cut in speed is a potential option to reduce collision risk (Barrios & Rodriguez, 2004), with relatively minor impacts on generation potential.

Operational modifications: There are a variety of options available which are capable of mitigating potential impacts, particularly collision risk. These include temporary shutdown (e.g. during periods of peak activity), seasonal shutdown and shutdown on demand. Selective stopping (temporary shutdown or shutdown on demand) of turbines has been used at a number of sites around Europe to reduce collision risk. There is evidence from a number of sites that appropriately implemented shutdown can be used successfully to reduce collisions (Ronconi *et al.*, 2004; Smallwood *et al.*, 2007; 2009; Cook *et al.*, 2011; de Lucas *et al.*, 2012). Some systems use radar in conjunction with trained observers. Whilst automated systems are under development, there is limited evidence available to date on how effective they might be. However, shutdown should be seen as a mitigation measure of last resort, and not a substitute for location and design considerations to minimise adverse impacts.

Modification of bird activity

Visual measures: Careful design of lighting options is needed to minimise potential attraction effects, for example, through the use of intermittent rather than continuous navigation lighting (Drewitt & Langston, 2006; Cook *et al.*, 2011). Painting with ultraviolet paint (Young *et al.*, 2003) or other forms of markings merit further investigation (e.g. Hodos *et al.*, 2001) as results to date have been equivocal or not adequately assessed.

Deterrence: Acoustic deterrence has been suggested as an option, although there are good reasons why this is likely to be unsuccessful (for review see Dooling, 2002), as has the use of decoys to influence behaviour (Larsen & Guillemette, 2007).

See also *Modification of habitats within and outside the site.*

Modification of human activity

Employment of ecological staff: The employment of a specialized ecologist, along with implementation of a comprehensive Environmental Management Plan is an important mechanism to ensure that all construction, operation and maintenance activities are carried out in the least damaging way possible. Developers have the option to fund posts for ecologists and community engagement officers, to aid conservation and understanding of wildlife needs.

Methods used: Changes to practices (particularly during construction activity) can be made to minimise habitat loss or damage; noise and other sources of disturbance. These should be set out in detail in the Environmental Management Plan for the site.

Timing of activity: Construction works and maintenance activity and movement of staff and vehicles and/or boats, can all be timed to minimise disturbance during key periods, such as the breeding season or when foraging birds are likely to be present.

Design solutions: Screens (natural or man-made) can be used to hide regular activity; restriction of access (public and staff) to sensitive areas/landscapes; routes used by staff and vehicles/boats (construction and maintenance) can significantly reduce disturbance issues.

Modification of habitats within and outside the site

At certain sites it may be necessary to prepare a Site Management Plan (also known as a Habitat Management Plan), detailing management measures that are designed to mitigate harmful habitat changes and other impacts following wind farm construction, and to provide plans for habitat enhancement as appropriate (Drewitt & Langston, 2006).

Minimise fragmentation and habitat disturbance: As detailed elsewhere in this report the destruction and/or fragmentation of sensitive habitats can be a cause of ecological impact, so designing sites in such a way as to avoid these impacts is a valid mitigation option. Impacts such as increased fire risk might be mitigated by creating scrub free areas around turbines (CFPA Europe, 2010).

Buffer zones around important habitats or features: Certain landscape features are particular attractive for birds, for example areas of rough grassland or water features (ponds and ditches) are often key foraging habitats for raptors. Leaving buffer zones between turbines and such features is likely to both reduce collision risk and minimise displacement impacts (Cook *et al.*, 2011). If regularly used nest sites are present in the area (for example of long-lived raptors), buffer zones may be used to minimise disturbance and reduce collision risk (Bright *et al.*, 2009). For other species, less prone to disturbance, alternative nest sites may be created to compensate for those lost through displacement.

Deterrence (or avoidance of attraction): Management measures designed to reduce the attractiveness of habitats within a wind farm are potential options, for example the reduction of collision risk by reducing sward height of grassland and thus decreasing the attractiveness to foraging wildfowl or raptors. However, such measures are likely to increase *de facto* displacement and therefore, are likely to add to the need for off-site habitat based mitigation to counteract habitat loss.

Enhancing habitats on-site: In certain circumstances impacts such as habitat loss and displacement might be mitigated through on-site enhancement of habitats. However, in such circumstances care must be taken that such measures do not create new risks, in particular raising collision risk. In addition, unintentional changes in habitats after construction (for example, through reduced grazing intensity or use of turbine bases for shelter by grazing animals) might produce habitat ‘enhancements’ resulting in attraction (increased activity) of birds vulnerable to collision risk (see *Section 1.6.1*).

Creation of alternative habitat off-site: There is a plethora of options for off-site creation or improvement of existing habitat, to mitigate impacts on individual birds or populations. Whilst these options can be used to mitigate impacts that are due to occur within the within the wind farm there is clearly overlap between measures which are considered mitigation and those which are classified as compensation (offsets) or enhancements. Care must be taken that habitat creation or improvement to make up for habitat loss within protected areas is viewed as compensation. This is particularly important when considering projects affecting Natura 2000 sites in the EU (European Commission, 2010). A good example of offsite mitigation is detailed by Walker *et al.* (2005). They showed that the creation of suitable foraging habitat for golden eagle off-site can be effective in replacing lost habitat (through displacement) and possibly has reduced collision risk by drawing activity away from the wind farm.

Table 1. Potential mitigation options		
Measure	Options	Examples of potential management options
Site based	Site design	Number of turbines; spacing; micro-siting
	Infrastructure	Undergrounding or marking power lines; relocating roads/tracks
	Layout	Grouping turbines; orientation of rows; corridors
Turbine based	Turbine design	Tower type; hub height; blade length
	Repowering	Replacing existing turbines with fewer, larger ones
	Remodelling	Deletion or moving location of troublesome turbines
	Operational measures	Shutdown periods; cut-in speeds; removal of old turbines
Bird behaviour	Visual measures	Intermittent warning lights; UV paint or markings (untested)
	Deterrence	Acoustic deterrence; decoys to influence behaviour
Human behaviour	Staffing	Employment of an 'Ecological Clerk of Works'; ecologists; public engagement officers
	Construction	Timing to avoid sensitive periods; site sensitive practices; design changes; screening activity
	Timing	Avoid activities (construction, maintenance) at key periods
Habitat modification	Landscape	Minimise fragmentation and habitat disturbance; buffer zones to important habitats or features
	Deterrence	Avoidance or removal of attractive features
	Habitat enhancement	Creation or improvement of on-site or off-site habitats to mitigate or improve resources for birds

2.3.4.2 Mitigation for impacts of offshore wind farms

There are few options available for onsite mitigation of impacts of offshore wind energy. Therefore, most discussion of potential mitigation measures has focussed on measures aimed at improving productivity and survival of birds at colonies where impacts are predicted to occur (Furness, unpublished⁴). Management options to increase productivity and/or survival are mostly site and species specific, and include options such as closures of key fisheries, provision of nest platforms, supplementary feeding, the cessation of culling, reducing disturbance, fencing colonies and in particular predator control. However, as adult survival is known to be the most important demographic parameter in determining population growth rates for seabirds (e.g. WWT Consulting *et al.*, 2012), it is clear that any measures aimed at primarily at improving productivity will need to be very effective to mitigate for loss of adult birds.

2.3.4.3 Compensation (Biodiversity Offsets)

In cases where mitigation measures are insufficient to avoid or minimise estimated impacts on birds, compensation can be used to offset such impacts, in cases where the project is consented as the benefits of the proposal are seen to outweigh the environmental costs. Compensation should be a last resort and only be considered if mitigation measures will not reduce adverse impacts to an acceptable degree. Triggers for additional compensation measures, should be well defined, bounded and feasible to implement, so the developer will have an understanding of any potential additional future requirements (Anderson *et al.*, 2007). Compensation for habitat loss should offer comparable habitat in the vicinity of the development (or the population requiring compensation), and should normally be in place prior to the impact occurring, wherever possible. 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. Site based compensation measures could include a range of potential options including supplementary feeding, predator control, fencing colonies and reducing disturbance.

It should be noted that compensation for adverse impacts on a Natura 2000 site (within the EU) only comes into play if it is proven that there are no alternative solutions to the proposal, and that it must be carried out for imperative reasons of overriding public interest (IROPI) (see Articles 6(3) &

⁴ Furness, R., MacArthur, D., Trinder, M. & MacArthur K. (unpublished) Evidence review to support the identification of measures that could be used to compensate or mitigate offshore wind farm impacts on selected species of seabirds. Report for CEFAS by MacArthur Green, Glasgow, UK.

6(4) of Directive 92/43/EEC). In such cases, compensation measures must be put in place to ensure that the overall coherence of Natura 2000 is protected (see European Commission guidance (2010)).

2.3.4.4 Enhancement

Ecological enhancements are improvements that go beyond measures required to mitigate or compensate for damage to species or habitats. Developers often provide incentives to make their proposals more readily acceptable to local residents, such as paying for community facilities. Providing attractive and wildlife-rich habitats is another way to provide community benefits, and to contribute to local and national biodiversity strategies and targets. However, habitat enhancement within the wind farm area requires careful planning and may need further associated measures to avoid increasing the risk of collision. Enhancements can include both positive land management changes as well as the creation of wildlife habitats both inside and outside of the development area.

Area	Measure	Examples of potential management options
Onshore	Positive land management	Reduced inputs (fertiliser and pesticides); crop type/ husbandry; sward height; restocking hedgerows; stocking densities
	Creation of wildlife areas – on-site	Uncropped areas; wetland features, drain blocking; tree removal; habitat restoration
	Creation of wildlife areas – off-site	Uncropped areas; wetland features, drain blocking; tree removal; habitat restoration
	Refuge establishment	Creation of wildlife friendly area which developers can buy into
	Contribution to knowledge base	Ecological data collection; post-construction monitoring; improved methodologies
Offshore	Reef effect	Substrate for bivalve communities; artificial habitat for invertebrates; shelter for marine life
	No-take zones	Curtailed of fishing within or outside of wind farm boundary
	Reduced disturbance	Less boat traffic; reduction in aggregate extraction; fencing colonies
	Improved productivity/survival	Predator control; fencing colonies; nest platforms; supplementary feeding; cessation of culling
	Contribution to knowledge base	Ecological data collection; post-construction monitoring; improved methodologies

Where mitigation or compensation are proposed to alleviate damaging impacts, the effectiveness of prescribed targets should be assessed through thorough post-construction monitoring, and a contingency plan should be available in the event of it not meeting those targets.

2.3.5 Assessment and Monitoring

It is clear that there is a need for thorough understanding of bird distribution and how this changes over time to inform site selection. In addition, objective baseline studies are required to inform site assessments in order to identify potential negative effects on birds, other wildlife and their habitats. Finally, there is a need for post-construction monitoring at consented installations where there are environmental sensitivities. There is also an urgent need to fill some of the evidence gaps identified in *Section 1.7.3*.

Many studies are of inadequate duration to provide conclusive results. Others suffer from a lack of ‘before and after’ data (or wind farm area and reference area comparisons), or fail to address relevant factors such as collision risk and differences in bird behaviour (e.g. between night and day, or

breeding and non-breeding periods). Many are of insufficient spatial scale to provide information on site and regional distributions, or to allow comparison between wind farm impacts and regional population trends. This is even more evident in the marine environment, primarily due to the large fluctuations in seabird numbers in a given location (Maclean *et al.*, 2013). For example, extending the duration, frequency and spatial extent of visual aerial surveys has been predicted to increase the probability of detecting changes (Vanermen *et al.*, 2011; 2012), but not to a desirable level (e.g. > 80%). The change to digital aerial survey methods offers the opportunity for more effective study design with sufficient power to detect change (see *Section 2.3.6*).

The use of standardised study methods (e.g. Gilbert *et al.*, 1998; Camphuysen *et al.*, 2004; SNH, 2005; 2010*b*) and consistency in their application are vital to ensure comparability of bird distribution and abundance before, during and after construction, in the wind farm area and a reference area (BACI: Before-After Control-Impact), and between sites. Standardisation in data collection allows the development of standardised analytical methods which ensure a consistent approach to risk assessment and aid the identification of significant impacts and enables comparison between sites. In many countries there remains an urgent need for best practice guidance on both study methods and data analysis, to inform the EIA process.

It is recommended that a minimum one-year baseline field study (two-years offshore) should be undertaken to determine the use of the study-area by birds and to identify which, if any, species potentially will be adversely affected. Post-construction monitoring should be designed in such a way as to enable short- and long-term effects and impacts to be distinguished and to provide information to enable them to be satisfactorily addressed. Research and monitoring should encompass all of the potential effects of wind farms, including population level effects, disturbance/displacement, barriers to movement, collision mortality and habitat loss or damage as well as cumulative and in-combination effects. However, monitoring requirements should be proportional to the size of the development and the scale of the risks/impacts, and so some form of targeting will usually be needed. In addition, the effectiveness of mitigation options such as different wind farm layout, turbine design and operational configurations should also be examined.

Research and monitoring should be implemented by national governments in conjunction with the wind energy industry and in consultation with relevant experts, to improve understanding of the impacts of wind farms. Research and post-construction monitoring at several sites will be necessary to determine the extent of impacts, to investigate population level effects and to identify acceptable solutions, where appropriate. The results of research should be published in international scientific journals in order to ensure dissemination and maximise understanding. This will be an iterative process that should inform decision-making, appropriate site selection and wind farm design. Post-construction monitoring should also be used to inform adaptive management, identifying potential high impact turbines or unforeseen challenges and enabling an effective response to minimise impacts.

The ecological data which is generated as part of any monitoring processes (either pre-construction assessment or post-construction monitoring), should be made available and accessible to the wider scientific community to enable independent validation.

2.3.6 Best Practice Study and Analysis Protocols

This section discusses in detail some of the methods and protocols for undertaking risk assessments, which can be used to produce predictions of impacts that may be relied upon with a degree of confidence. The section begins with guidance on defining study objectives and discussion of survey techniques that are available, before going through study methods and protocols for assessment of impacts, reviewing methods of assessing/predicting effects/outcomes and finally reviews methods for monitoring effects or verifying impacts.

2.3.6.1 Study Objectives and Survey Techniques

Consultation of existing information sources will provide baseline data, assist with the identification of priority species and issues, highlight information gaps and help to inform the focus of new data collection. Information on numbers, distribution, and timing of presence for the range of bird species occurring at the site will need to be obtained from a combination of existing data sources and targeted surveys. Bird sensitivity indices have been produced to assist with the identification of

likely priority species for environmental impact assessment and focal studies (Garthe & Hüppop, 2004; Desholm, 2009; King *et al.*, 2009; Furness & Wade, 2012; Furness *et al.*, 2013) (see *Section 1.7.2*). Identification of site designations (SPAs, national protected areas etc.) and the proximity to designated sites will determine the level of test that will have to be met and so the level of study that will be required. Information will be needed for the site and, for context, for the relevant geographical region in which a project is located, bird populations using the site will need to be placed in biogeographical, national, regional and local contexts.

Minimally year-round studies for one year will be necessary for a pre-construction assessment for an EIA, to identify the range of species using the site and any seasonal patterns in their occurrence. For those sites with few existing data or which are used by species that show high levels of inter-annual variation, a minimum of two years data collection should apply, notably at sea. This requirement represents a compromise – more years of data collection will provide information on inter-annual variation in species, numbers and distribution, but each extra year of data collection may unnecessarily delay a planning application. The requirement for data from additional years will be dependent upon the location, species present and availability of existing data and, ideally, should be identified at the scoping stage. In the marine environment, a minimum requirement of two years' data collection has been implemented in the UK because of the paucity of contemporary existing data. There, the main source of data on distributions and abundance of seabirds has been European Seabirds at Sea (ESAS), which is a substantive dataset, but much of it is now in excess of twenty years' old and coverage is patchy.

All studies require clear objectives. Data collection for pre-construction assessment enables characterisation of the proposal area and contextual information for the surrounding area, to inform the EIA. For sites that obtain planning permission, continuing environmental studies before, during and after construction (i.e. during operation), need to be tailored to the specific requirements of the site and associated species. Repeatable, standardised methods are essential. Before-After-Control-Impact (BACI) studies are generally recommended, comparing the situation before and after construction on the impact site (wind farm) and a closely matched reference (control) area (e.g. Anderson *et al.*, 1999; Langston & Pullan, 2003; SNH, 2005; 2010*b*; Strickland *et al.*, 2011). Such an approach has a greater likelihood of detecting changes attributable to the wind farm rather than to other contemporary changes. Study design should incorporate an analysis of statistical power necessary to detect change (e.g. Vanermen *et al.*, 2011; 2012; Maclean *et al.*, 2013).

The impact study area should comprise the wind farm plus a suitable buffer, the size of which will be dependent upon the bird species present, but is likely to be of the order of 500 m to 2 km radius on land and up to 4 km radius or larger at sea. The reference area should be beyond the buffer, be as closely matched as possible to the impact site in terms of habitat and topography, and of similar size to the development site. Finding suitable control/reference sites is often difficult, which can undermine the statistical power of this approach. Before-After-Gradient studies may be applicable, instead of BACI, notably at offshore wind farms, with more intensive work within the wind farm and buffer, and more extensive methods over a wider area (Thaxter & Burton, 2009). Supplementary environmental information will aid interpretation.

Observations must cover diurnal/nocturnal periods, tidal cycles (if appropriate to the site and species present) and, as far as possible, include all representative weather conditions. It will be difficult (if not impossible) to obtain data during inclement weather, such as fog, heavy precipitation or strong/gale-force winds, for reasons of limitations of observation methods and health and safety, notably at sea or in the uplands. It is feasible to use existing weather data to determine the frequency of poor weather conditions likely to increase collision risks for birds and to incorporate other sources of information in the risk assessment. For example, information on seabird wrecks, ringing recoveries etc.

Vantage point observations are most usual for studying the flight behaviour of focal bird species vulnerable to collision, collecting information on flight direction, destination, height and purpose (SNH, 2005; 2010*b*). Observations of flight behaviour will contribute to an assessment of collision risk. Collision risk models are widely used in collision risk assessment (Band *et al.*, 2005; 2007; Band, 2012), but there are contradictory views as to their utility (Chamberlain *et al.*, 2005; 2006) (see *Section 2.3.6.4*), compounded by the difficulties associated with visual estimation of flight height and

distance from observer. As tracking technology develops, bird-borne telemetry is an increasingly promising tool for obtaining data on bird flight behaviour, especially with the addition of high resolution altimeters to permit 3D data gathering, before, during and post-construction. Currently, these tools are applicable to a small but growing group of species as size/weight and costs decrease.

In addition to visual observations, acoustic monitoring, the use of radar, video cameras and thermal imagery all offer potentially useful tools. Radar can be applied round-the-clock to assess migration volume and temporal and spatial variation in other forms of flight activity that would be otherwise difficult to record, but it requires supplementary information to confirm species identification. Radar is also a useful tool for assessing flight response to wind farms (e.g. Desholm & Kahlert, 2005; Plonczkier & Simms, 2012). Camera and thermal imagery technologies can be applied to record flight responses close to wind turbines (e.g. Walls *et al.*, 2009) and potentially as part of automated systems for turbine shutdown. Acoustic monitoring may be useful for monitoring flight activity in the vicinity of wind turbines, although not all bird species call in flight, but there are standard protocols for dealing with auditory data (e.g. Rempel *et al.*, 2005; Dawson & Efford, 2009; Efford *et al.*, 2009). Other research approaches that may be relevant include various tracking technologies, for example radio telemetry, satellite tags and GPS data loggers, monitoring of breeding colony occupancy and productivity. This is not an exhaustive list and methods need to be applied that are proportionate and appropriate to investigate specific issues for focal species. Remote techniques are particularly applicable (and indeed necessary) offshore.

2.3.6.2 *Synthesis of Onshore Study Methods*

Collision risk

Currently the key input data into collision models is derived from field observations obtained during Vantage Point (VP) watches. These data record the bird flight activity within the rotor swept zone (RSZ), which is variable depending on the specifications of the turbines, although the turbine dimensions are often not available at the time of pre-construction survey. VP surveys are carried out from one, or more commonly several, fixed viewpoints (the VPs), which afford a good view over the survey area or subsection of survey area. Ideally the VPs should be outwith the actual survey area, but looking into it. However, in practice, especially with large sites, this will be impossible. Most VPs are designed to watch over an arc of radius 2 km with a central angle of 180°. Some American and Australian surveys use a circular observation area, with the VP in the middle (for example see Erickson *et al.*, 2003). However, this is likely to increase observer effects on bird behaviour and thereby influence observed activity (Madders & Whitfield, 2006). As far as possible, all parts of the study area should be within 2 km of a VP. While overlap of visible areas of VPs is undesirable, in practice it is hard to avoid, and can be factored into subsequent analysis. Under most circumstances, surveys should be designed so that watches from overlapping VPs are not carried out simultaneously, however, there can be advantages to simultaneous VP watches, particularly in terms of tracking bird movements throughout a site as a whole.

Bird activity is likely to vary in intensity temporally over a site. The surveys must therefore be designed and stratified to take this into account, with an adequate amount of time spent at all times of day and across the seasons to accurately characterise activity levels at different times. Depending on the species present, focal watches may have to be carried out at key times of day or night in order to detect important bird movements. For example, golden plover *Pluvialis apricaria* will make most commuting flights around dawn and dusk (Byrkjedal & Thompson, 1998), and if present on the site, the timing of watches must reflect this behaviour. Other behaviours will vary in intensity seasonally, for example, raptors will display more early in the breeding season than later on (Hardey *et al.*, 2009). Any intensive observation periods designed to capture such behaviours will bias the inputs of collision risk models unless corrected for in the analysis.

Adequate time must be spent at each VP; current guidelines (SNH, 2010b) suggest a minimum of 36 hours per VP per season (breeding and non-breeding). Sensitivity analysis of observations of white-tailed eagles (Douglas *et al.*, 2012) suggests that this is adequate, but the authors noted the inherent variability of observations, the need for further analysis for other species, and that additional hours of observation do result in improved estimation of collision risk. The more heterogeneous flight activity is at a site the more hours of observation are likely to be needed to capture a good

representation of activity levels. For this reason guidance often recommends 72 hours of observations for raptors and other species that can be absent from an area for long periods of time but then appear and spend relatively short bursts of intensive activity (NE, 2010; SNH, 2010b).

A minimum of one complete year's observation must be undertaken, but in practice at least two full breeding seasons will be required for many species. This is because some species, such as hen harrier and short-eared owl *Asio flammeus*, will show marked variation in their breeding behaviour in response to variation in prey densities, which can undergo cyclic changes (Korpimäki & Norrdahl, 1991; Redpath *et al.*, 2002). Therefore, one season's observations may not accurately reflect typical usage of the site by these species, and could result in an over- or under-estimate of collision risk. Species with multiple nest locations, such as golden eagle (McLeod *et al.*, 2002) may also exhibit variable levels of activity at a particular site from year to year, depending on the location of alternative nest sites.

Inherent in VP data are a number of potential sources of error and bias, such as missed observations, observer acuity and ability to detect flying birds (Madders & Whitfield, 2006). Such errors can be minimised by the use of experienced and trained observers. Other errors, such as the estimation of flight height cannot be fully eliminated without detailed ground truthing (such as comparison with radar measurements), and should therefore be acknowledged in the presentation of results.

Displacement

Displacement can occur in two ways, displacement from foraging areas (breeding/non-breeding), and displacement from breeding/roosting areas. The former can be assessed from data collected by VP watches, the latter must be estimated from breeding bird surveys. Detailed survey methods are available for most species (e.g. Gilbert *et al.*, 1998; Hardey *et al.*, 2009), although some, such as short-eared owl remain difficult to survey (Calladine *et al.*, 2010). The standard method for surveying the majority of species of open upland habitats follows that of Brown & Shepherd (1993), whereby all the survey area is walked to within 100 m, landscape features which may be of potential ornithological importance are approached and the location of all birds showing behaviour indicative of breeding are plotted. The method can be adapted to account for abundant species, such as meadow pipit and skylark (e.g. Pearce-Higgins *et al.*, 2009). Surveys should be carried out in suitable conditions avoiding strong winds, heavy precipitation and poor visibility. This method is sensitive to the timing of visits, so to minimise the likelihood of missing breeding birds, for example during incubation, three full survey visits should be made, throughout the breeding season. This method is not adequate for breeding raptors, some waders (e.g. whimbrel *Numenius phaeopus* and dotterel *Charadrius morinellus*) and woodland grouse species and therefore bespoke methods should be used for these species; however, well established methodologies are available (e.g. Gilbert *et al.*, 1998; Hardey *et al.*, 2009).

For lowland open habitats, territory mapping techniques such as British Trust for Ornithology (BTO) Common Birds Census (CBC) (see *Useful websites* section for link) are appropriate, although as with upland areas, some species specific surveys may be required, particularly for species of conservation interest. Variations on the CBC will also be appropriate for relatively open woodland, such as native deciduous woods. For denser forestry, such as conifer plantations, where structural density inhibits an observer's ability to access and record the activity of all the birds present, point counts will be more suitable (Bibby *et al.*, 1985; 1992). Essentially this will simply provide a list of all the species present. However, where species of conservation interest are known to be, or likely to be present, more detailed surveys should be carried out to target these species.

2.3.6.3 Synthesis of Offshore Study Methods

This section does not repeat standard onshore survey methods that can be found above, but instead reviews some of the factors to consider in terms of study methods for offshore projects.

For offshore wind farm projects, most baseline data collection and distribution monitoring have historically used visual aerial and/or boat based methods (Camphuysen *et al.*, 2004). Visual aerial surveys are defined here as aerial surveys in which observers record birds in real time during low elevation flights, to distinguish this method from digital aerial surveys (see below). These techniques

have different advantages and disadvantages. Aerial surveys enable coverage of large sea areas in a relatively short time frame, including shallow inshore waters. Boat-based surveys permit behavioural observations to be made and are useful for assessing numbers and distribution of auks in particular, but are slow to cover large offshore survey areas posing a particular problem in winter, due to short day-length and inclement weather, making it difficult to achieve the required seasonal coverage. Boats have the advantage of facilitating simultaneous collection of environmental variables.

Increasingly, digital aerial surveys are replacing visual aerial survey techniques (Thaxter & Burton, 2009; Buckland *et al.*, 2012). Digital aerial survey uses high-definition video or stills cameras attached to the aircraft. This transition has taken place for several reasons. In the UK, low elevation flights are not permitted in most operational wind farms owing to health and safety concerns. Digital aerial surveys have the advantages of flight capability at higher altitude, thereby reducing the risk of disturbance to birds, providing a potentially permanent record of each survey (albeit with large data storage requirements) thereby facilitating re-analysis using different analytical techniques or automated processes. Digital aerial techniques also offer adaptability to survey design more compatible with statistical analysis for example using a Before-After-Gradient approach to assessing displacement (Buckland *et al.*, 2012). The main disadvantage of the approach has been species identification, particularly distinguishing closely similar species, such as auks, although advances in camera technology and improved application, are permitting improvements over time. To use visual aerial surveys prior to construction, only to have to change method during and post-construction, would lead to a change in method which would make the assessment of change much more challenging and risk inability to determine change that might be attributable to the wind farm. In the interim, some offshore wind farm developers are using digital aerial survey as their main survey method with the addition of boat-based surveys to provide proportional allocation of species identification.

There are two main analytical approaches used to estimate populations from survey data. Design-based analysis assumes random sample plots that are representative of the whole study area. Mean density values calculated from the survey data are applied to the whole area. Model-based analysis uses the survey data from the sampled area to extrapolate to the whole study area by applying models which incorporate bird density and predictive environmental covariates (Buckland *et al.*, 2012). A grid of cells is defined over the study area and bird density estimated for each cell. The sum of these bird density estimates provides the population estimate for the study area. Model-based survey design permits changes in abundance and distribution to be monitored, as part of a before/after survey design, thereby enabling assessment of the effects of a wind farm including evidence of any displacement.

2.3.6.4 Collision Risk Modelling

In order to correctly assess the potential impact of any wind farm development, as part of the Environmental Impact Assessment procedure, some indication of potential bird mortality as a consequence of the development must be carried out. There is a growing body of evidence that bird collision with turbines can be an important source of mortality post construction (e.g. Garvin *et al.*, 2011; Ferrer *et al.*, 2012). However, it is necessary to understand when such collisions will occur and in what numbers. This is of particular importance when species with the potential to collide are of conservation concern since the incidence of collision will increase mortality, with implications for population size and conservation status.

A spatial modelling approach can be used to assess potential impacts, identifying the areas of greatest sensitivity to development (e.g. Williams *et al.*, 1996). This can be carried out for single species (McGrady *et al.*, 1997; McLeod *et al.*, 2002), or on a landscape scale for multiple species (e.g. Bright *et al.*, 2008). As such it can be a valuable tool for screening of potential sites, but cannot explicitly determine potential mortality through collision, since there is no consideration given to the flight patterns of the birds. Collision Risk Models (CRM) attempt to quantify the number of bird collisions with turbines that will occur post-construction. This is achieved by explicit consideration of bird interactions with the turbines, based on mathematical equations, incorporating descriptive data not only of the turbine dimensions and configurations but also of the bird characteristics and use of the area, the latter most often obtained by field survey. It should be pointed out here that field survey data

of bird activity and use of a site is often limited, especially with bird activity that is hard to survey such as migrating passerines at night.

The first CRM, created by Tucker (1996), was inevitably rather unsophisticated, as it neither accounted for rotor swept volume nor avoidance by birds. These limitations were overcome in the broadly similar Avian Risk of Collision (ARC) model (Podolsky, 2003; 2005), although this model has not been widely adopted. Other subsequent models include the Biosis Model, which is widely used in Australia (Biosis Research, 2003; Smales *et al.*, 2013), and the Band model (Band *et al.*, 2005; 2007), which is used and recommended in statutory guidance (SNH, 2000; 2005; 2010*b*) in the UK and to a large extent in Europe. Recently the Band model has been reviewed and updated for application offshore (Band, 2012). Common to all CRMs is the potential for erroneous estimates of collision risk due to simplistic assumptions about bird behaviour that are implicit in many of the input parameters (Madders & Whitfield, 2006).

More recently, Eichhorn *et al.* (2012) combined both the spatial modelling approach with CRM, to produce a spatially explicit simulation model. However, the model is only applicable to central place foragers, i.e. birds returning to a fixed point, such as a nest, and so only of use for certain species at certain times of year, such as the breeding season. It makes no allowance for, for example, the floating immature cohort of a population, that can be particularly important for raptor and seabird population dynamics (e.g. Negro, 2011).

The basic Band model involves three stages (Band *et al.*, 2005; 2007). The first stage estimates the number of birds passing through the rotor swept zone of the wind turbine(s), based on site-specific bird survey data. The second stage assesses the probability of a bird colliding if it flies through the rotors of an operational wind turbine. Multiplying the outputs from the first and second stages of the CRM yields an estimated number of collisions, assuming no avoidance by the birds. In most situations, at least some measure of avoidance is expected (there are some exceptions for terrestrial birds, hence it cannot be assumed that avoidance will occur in all situations at sea either). The third stage of the model is to apply a correction factor to the collision risk calculations, to take into account various sources of uncertainty in the model, including avoidance (May *et al.*, 2010). Arguably there is now a fourth stage where the resulting collision figure is further adjusted to account for factors such as turbine shutdown and any site specific factors which might reduce risk but are not incorporated into the collision risk model.

There are two classes of bird data required for modelling, site specific and generic data, both classes are variable in their precision. Site specific data are collected by field studies: usually direct observations of bird behaviour at the site pre-construction. These can have inherent problems, such as missed observations, observer variability and detectability of flying birds. Site-specific field data, unless collected remotely, for example by radar, will also be subject to observer bias to a greater or lesser degree. Garvin *et al.* (2011), analysing data at wind farms in Wisconsin excluded height data from one researcher as the estimations were consistently lower than other observers. However, such information is not usually available, and while it is widely acknowledged that biases are likely (Madders & Whitfield, 2006), these are rarely quantified in any meaningful way.

The first stage of the Band model relies on information about bird flight elevation which is mainly estimated by visual observers and is subject to considerable error, requiring a precautionary approach in allocating proportions of birds at the boundary of the lowest blade sweep in particular, i.e. flying below the rotors or within the rotor swept area. This error may be compounded if flight height has been estimated for only a small proportion of birds observed, then extrapolated to the estimated numbers of birds within the area of the wind farm proposal. Cook *et al.* (2012) have reviewed flight height information, from the literature and wind farm reports, with the intention that in the absence of site-specific estimates or where the sample sizes are small, information about relative proportions at collision risk height might be substituted in the collision risk models. They estimated the variance around mean estimates of flight elevation, but the study does not discriminate between flight behaviours, and reflects the range of flight heights observed across all sites. This matters if there are important behavioural differences, and associated susceptibilities to collision, at a particular site, which will not be reflected if generic data from the meta-analysis is used. Caution should therefore be taken when extracting results from meta-studies to use for proposed wind facilities, and effort should be made to obtain local, contextual information. Increasingly, digital aerial surveys are replacing

boat-based surveys of large offshore areas, and techniques for estimating flight height are being developed. Currently, these estimates tend to allocate a higher proportion of bird observations to higher elevations than is the case for boat-based observations – clearly this is an important difference in terms of assessing the proportion of birds observed at collision risk height, which needs further investigation.

Recently there have been further refinements of the Band model for use in the assessment of offshore wind farms (Band 2012), although the new models are also likely to have implications for onshore developments. This revised model has four options for calculating collision risk:

- Option 1: Is same as the basic ‘Band’ model. It assumes a uniform distribution of bird flight heights within the rotor swept area, and utilises data on bird movements collected on site, usually from boat-based surveys in which the observers generally assign flight height to three large bands - below rotors, within rotor swept height or above the rotors;
- Option 2: Is the same as the basic model. It uses generic flight height data, mainly from boat-based collection, taken from the BTO review of offshore wind studies by Cook *et al.* (2012). The rationale being that it presents a larger, perhaps more representative dataset than the data collected at any one site;
- Option 3: An extended model which uses the generic flight height data from Cook *et al.* (2012), allocated to 1 m bands by a further model also developed by the BTO. This extended model is designed to take into account both how flight height tend to be skewed toward the lower end of the potential collision window, and that there is a lower risk of collision further from the rotor hub. This model therefore results in a lower predicted collision risk; and
- Option 4: The same extended model as Option 3, using the additional BTO flight height model to allocate site-specific data to 1 m bands, if sufficient numbers of observations have been made.

There remains a debate as to the validity of the extended model, both in terms of how the flight height distributions were determined and how the model accounts for uncertainty in the form of avoidance rates. As such, it is currently recommended that if the extended model is used, at least two of the options (e.g. one and three), are presented. Further empirical data are required to validate both the flight height distributions and the extended model itself.

In terms of generic data used in the second stage, some input parameters are fairly well evidenced, others are not. For example, of the inputs for the Band model, bird body length and wingspan are well known, but flight speed is not. Flight speed is usually derived from a small data set in the literature, when in reality it is highly variable, dependent on numerous confounding variables such as weather, breeding status and behaviour.

The fundamental assumption of CRMs, that collision mortality increases with flight activity, has been demonstrated by some studies (Smallwood *et al.*, 2009), however, others have not found this to be the case (Orloff & Flannery, 1992; Fernley *et al.*, 2006; Whitfield & Madders, 2006; de Lucas *et al.*, 2008; Garvin *et al.*, 2011). This is likely to be in part because the preconstruction screening process has prevented most wind farms being constructed in areas of high bird activity, with the notable exceptions cases such as of Altamont Pass, Smøla and Tarifa (see *Section 1.3.1*). However, it is clear that collision with wind turbines will not only be governed by abundance but also by behaviour, morphology and topographical factors (Ferrer *et al.*, 2012). A distinction should be made between bird abundance and activity levels. Flight activity may vary with number of birds, so frequent activity by a low number of birds may result in a similar level of estimated risk to infrequent activity by a large number of birds. The frequency of weather conditions likely to adversely affect risky flight behaviour, particularly for migrating birds, may be predicted from meteorological data to generate risk indices.

Avoidance

Avoidance rate (AR) as used in collision risk modelling include avoidance of the whole wind farm (sometimes called macro-avoidance) and close proximity avoidance of individual turbines (termed micro-avoidance) (Krijgsveld *et al.*, 2011; Band, 2012). What is termed the ‘avoidance rate’, as used in the Band model, is a misnomer; in reality it is a catch-all for biological and environmental

variability. The application of avoidance rate in practice has been used to account for variation in the model input parameters, including flight speed, flight type, inaccuracy in height recording etc., variability in collision risk under different conditions (daylight and night; fine weather and poor visibility; high winds or low winds etc.), which may explain the difference between ‘predicted/expected’ fatalities and ‘observed’ fatalities. In other words, avoidance rate is in reality a correction factor to account for the difference between predicted mortality and recorded mortality.

Avoidance rate has the greatest influence on model outputs, compared with modifying other model input parameters (Chamberlain *et al.*, 2006; May *et al.*, 2010). However, estimates of flight height and bird densities also have large influences on the model outputs. In stage 3 of the Band model the estimated number of collisions, before avoidance is multiplied by 1 – avoidance rate. Values for avoidance rate applied in these models usually range from 95 to 99+%, with 98% considered the default for offshore wind farms, pending evidence of actual behavioural responses (SNH, 2010a). Increasing the avoidance rate from say 98% to 99% halves the estimated number of collisions, i.e. from 2% to 1%.

The only true means of quantifying an ‘avoidance rate’ is via before and after impact studies, including carcass detection, either through remote sensing or by direct carcass searches, the latter provided suitable correction factors or fatality estimators are applied (Smallwood, 2007; 2013; Bernardino *et al.*, 2013). While there are a number of studies emerging that have done this, their applicability to all developments remains limited. This is largely related to proximity to large breeding colonies. Breeding birds are Central Place Foragers, in that they must return to the same location, the nest site, after each foraging bout, or series of bouts. This constrains their foraging flexibility, and means that they are more likely to show what can be perceived as ‘risky’ behaviours, such as flying through a wind farm, than birds free from such constraints and this will vary between species, and within species, for example mediated by prey availability, sex, breeding status.

A number of studies have attempted to refine avoidance rate, either by literature review or by post construction monitoring. A species-specific approach to avoidance rate must be taken, as susceptibility to collision will be strongly influenced by morphology and behaviour. Avoidance rates have been calculated for gulls and terns from carcass searches at onshore wind farms. However, these lack preconstruction monitoring and there remains considerable debate as to the applicability of the correction factors involved. For example, at Flanders on-shore wind farms, Brugge and Nieuwkapelle and the harbour wind farm at Zeebrugge, (Everaert & Kuijken, 2007; Everaert & Stienen, 2007) carcass searches were carried out, but without the context of pre-construction assessment. The authors concluded that for measuring collisions a “reliable, well-tested technique...is urgently needed”.

Following a literature review (Whitfield & Madders, 2006), guidance on avoidance rate for the hen harrier has been increased to 99%, largely because of the harrier foraging technique, whereby they quarter close to the ground. Similarly the avoidance rate for golden eagle was reviewed by Whitfield (2009) from data from four North American wind farms, and the authors concluded that 99% avoidance was probably precautionary. For swans and geese, following reviews by Fernley *et al.* (2006) and Pendlebury (2006) avoidance rates of 99% have been recommended (SNH, 2010a). In the case of wintering geese the guidelines have been recently amended to 99.8% (SNH, 2013), following a recent review of the evidence base, although the evidence to support this move is chiefly circumstantial (e.g. the absence of large numbers of recorded collisions). Based on data collected at Smøla (Bevanger *et al.*, 2010), the avoidance rate for white-tailed eagle has been set at 95% (SNH, 2010a). Whilst the attempt to derive ‘real’ avoidance rates is laudable, the recommended use of derived avoidance rates fails to acknowledge the point above – namely that the avoidance rate actually provides a mechanism to incorporate biological and environmental variability into the model, alongside the avoidance behaviour of birds.

Offshore studies include those at Egmond aan Zee wind farm, situated 10-18 km from the Dutch coast. Rigorous before and after studies, involving boat, aerial, radar and direct visual observations have been carried out (Krijgsveld *et al.*, 2011; Lindeboom *et al.*, 2011), and have shown that the largest far-field avoidance, i.e. avoidance of the whole wind farm, has been shown by pelagic seabirds, such as northern gannet, auks and divers. However, this remains a study of a relatively small wind farm, close to the coast, and away from major breeding colonies or cliffs. Similarly studies at the Danish wind farms at Horns Rev and Nysted, (Desholm & Kahlert, 2005; Petersen *et al.*, 2006) have

shown avoidance by pelagic seabirds, mainly on migration, but numbers are low, and again these sites are distant from any breeding colonies, in shallow water and close to shore.

Therefore while there has been considerable debate about the correct level of avoidance rate, little of it has been supported by empirical evidence from pre and post construction monitoring. SNH guidance, (most recently SNH, 2010a) has recommended a default rate of 98% on and offshore, apart from the species described above. An offshore review carried out for the Strategic Ornithological Support Services (SOSS) by Cook *et al.* (2012), stated clearly that “a value of 98% as recommended by SNH should be used as a precautionary avoidance rate until further evidence is available”. An update of the method, also for SOSS by the model’s original main author, Band (2012), acknowledged that there remain “uncertainties and variability in source data, and limited firm information on bird avoidance behaviour”. While the Dutch and Danish studies are of high quality, their applicability to large scale developments in offshore waters and pelagic breeding seabirds remains limited. Furthermore uncertainty remains as to the variability of other biological inputs into the model, which avoidance rate, in practice, should account for.

Further debate has involved the use of the terms macro and micro-avoidance. As such, most offshore studies have been measures of macro-avoidance, but there has been little consistency in the recorded species specific rates. Few studies measure micro-avoidance directly, i.e. record the behaviour of birds in the vicinity of turbines. In the absence of more studies, the distinction between macro and micro-avoidance offers little empirical clarity to discussions of avoidance rate as a model input.

Validation

It is a widely held view that collision risk modelling is overly precautionary, but the reality is that without empirical data we do not know whether model outputs bear any relation to actual outcomes; it may be that they are just plain wrong. In the meantime, comparison of model outputs, using a 98% avoidance rate as the default value for offshore wind farms, at least permits relative comparison of the magnitude of effect across different wind farm proposals.

In order to fully understand the processes involved in collision, and therefore to be able to correctly predict collision risk, rigorous post-construction monitoring is needed. However, generally there is a lack of such monitoring, and where it does occur, it is often of short duration and the data are treated as confidential (Rees, 2012). Such monitoring should include carcass searches; however, there exist a number of biases associated with such searches, such as search area, scavenger removal and search efficiency, and a consequent need to apply correction factors (Smallwood, 2007; 2013; Grünkorn *et al.*, 2009; Huso, 2010; Smallwood *et al.*, 2010; Korner-Nievergelt *et al.*, 2011; Bispo *et al.*, 2012; Bernardino *et al.*, 2013). Such correction factors, derived from mortality estimates, have to be applied with caution at potential sites that differ greatly from the sites for which they were originally calculated since there is likely to be much local variation in for example scavenger presence and vegetation structure. The use of trained dogs for carcass searches has several advantages over searches by people (Mathews *et al.*, 2013). The potential for carcass searches at sea is currently limited to nearshore developments (Newton & Little, 2009), and essentially impossible for those far offshore at the present time, although remote monitoring techniques are under development (see Section 2.3.6.5).

2.3.6.5 Collision Mortality Assessment

Monitoring of actual collisions is problematic. They are generally rare events and relying on visual observations alone is too time-consuming and impractical. Most onshore studies rely on corpse searches, but these too have their drawbacks and because of the limitations of the method it has to be assumed that the corpses found represent the minimum number of dead birds (Smallwood, 2007).

Collision searches require strict protocols to be adhered to, including calibration for: search effort; removal (scavengers); observer efficiency; vegetation/ground cover including the presence of water; non-fatal collisions; corpses landing beyond the search area (Winkelman, 1992). Visual searches for corpses by a human observer may be improved by the deployment of a trained dogs (e.g. Arnett, 2006; Bevanger *et al.*, 2010; Mathews *et al.*, 2013). Post-mortem is an important adjunct to corpse searches to enable the likelihood or certainty of death in connection with a wind turbine to be ascertained.

The preferred approach for corpse searches is to search within a fixed width transect of at least 50m width along each side of each line of wind turbines, using a zigzag search path to cover the whole wind farm and buffer zone. A hit bird may be carried for a considerable distance from the wind turbine, so additional parallel transects away from the turbine array may be useful, although Smallwood & Thelander (2008) found that 85-88% were found within 50 m of turbines. Whatever search regime is used, it needs to cover the ground adequately to maximise the likelihood of finding corpses. A search protocol incorporating a stratified programme of corpse searches is best, with a higher level of search effort during the main time-periods, but this should be on the basis of potential sensitivities as well as volume of bird movements/numbers of birds present. Ideally, a sensitivity analysis should be carried out to determine appropriate sample size of placed corpses, but bearing in mind comments above.

In view of the probability of scavenger removal, it is recommended that frequent searches are made, at least initially, for each season that focal species are present, marking found corpses and leaving them in situ to assess time to removal or carrying out experimental placement of marked dead birds (with leg tag or similar) to assess scavenger removal and search efficiency. Then apply search frequency accordingly and present information in raw and corrected forms. This may seem onerous for a small wind farm, but monthly searches without estimating the role of scavengers will yield information that may be highly misleading - if no dead birds are found, it may be because there aren't any or it may be due to high levels of scavenger activity. Useful references include Winkelman, 1992; Everaert & Stienen, 2007; Smallwood, 2007; 2013; Duffy & Steward, 2008; Grünkorn *et al.*, 2009; Huso, 2010; Smallwood *et al.*, 2010; Korner-Nievergelt *et al.*, 2011; Bispo *et al.*, 2012.

If placing carcasses for testing scavenger removal and search efficiency, these should resemble the species of interest as closely as possible. The palatability of different species should be considered and the consequent attraction of scavengers. Depending on the species of interest, appropriate surrogates for removal experiments include domestic poultry (e.g. geese), fresh dead or defrosted, not frozen, shot quarry species of wildfowl, or road casualties. The sample of placed carcasses needs to be adequate to provide results, but not so numerous that scavenger activity is greatly increased or capacity for removal is swamped (Smallwood *et al.*, 2010). The experiment should be carried out during the period that the key species of interest are present. However, the experiment also needs to be planned with minimum disruption to the presence of focal species, perhaps by selection of time of day to undertake searches.

Following placement of the carcasses, mark the location (spot of spray paint and GPS position to aid relocation and enable assessment of any movement, such as may indicate scavenger activity) make daily checks and record presence/absence of each carcass and signs of predation, location and distance moved etc. At the end of the first 7 days, removal rate can be ascertained, which may mean that in the second week the search interval could be increased to say 3 days. If any carcasses remain, continue through the third and possibly fourth week at reduced search intervals. This experiment will enable the appropriate length of the search interval check for wind turbine collisions to be identified as well as providing data for applying correction factors to any found collisions. If carcasses disappear within a few hours or days, monthly searches for collision fatalities are going to provide distorted results unless adequately corrected.

The use of remote techniques has been explored, notably for application offshore where corpse searches are impractical (Desholm & Kahlert, 2005). Thermal imagery (TADS) or video cameras have potential utility in assessing collision risk and near-turbine avoidance behaviour (Collier *et al.*, 2011; 2012), but are currently limited by the field of view that is achievable (Desholm, 2005). There has been some investigation of the use of contact or acoustic sensors to detect collisions (Pandley *et al.*, 2007; Wiggelinkhuizen & den Boon, 2010), but these require supplementary methods to identify the bird species involved, for example microphones and video cameras (Icanberry, 1991; Dooling, 2002; Pandley *et al.*, 2007; Wiggelinkhuizen & den Boon, 2010).

2.3.6.6 Displacement

Displacement, i.e. reduced bird density or absence from the vicinity of the wind turbines or whole wind farm footprint and possibly surrounding area too, equates to habitat loss. As with other habitat loss, there may be short-term or longer-term effects and birds may or may not adjust over time to the

presence of new structures in their environment if the habitat remains otherwise suitable. If alternative comparable habitat is not available or redistribution leads to increases in bird density that cannot be sustained, likely outcomes are breeding failure, increasing difficulty in meeting energy requirements, which may in turn lead to inability to attain breeding condition and/or reduced survival. Unlike mortality arising from collision, there may be a time lag to any mortality loss, depending on the critical requirement, time of year etc. when the habitat loss occurs (as discussed in detail in *Section 1.2*).

Furness *et al.* (Furness & Wade, 2012; Furness *et al.*, 2013) present a displacement sensitivity index for seabirds in Scottish waters, although it has wider applicability. Natural England (NE) and the Joint Nature Conservation Committee (JNCC) have prepared an interim advice note on how to assess the potential magnitude and consequences of displacement in seabirds in relation to offshore wind farm developments (NE & JNCC, unpublished). Their recommended approach requires estimation of the number of birds of a given species predicted to be at risk of mortality following displacement for a range of % displacement levels, from zero to 100%, and a range of putative mortality rates, from zero to 100%. They recommend highlighting values considered to be more realistic, on the basis of empirical evidence, in the resulting matrix. Similar matrices should be produced for each species and season in which the risk of displacement is considered to apply. It will be necessary to apply a buffer around a site, within which displacement will be likely to occur. The appropriate distance will be species specific, but might be in the region of 500 m to 2 km onshore or 2 to 4 km offshore (see *Section 1.2*).

Any assessment of displacement requires data collection before and after installation of the wind farm, using comparable methods and a study design that permits comparison of bird distribution and abundance before and after construction, with adequate power to detect change. Model-based survey design, applied before and after construction, permits assessment of displacement effects of a wind farm (see *Section 2.3.6.3*). McDonald *et al.* (2012), commissioned by Marine Scotland, developed a 'proof of concept' displacement model for common guillemots, on the Isle of May, Scotland, which estimated the effects of a range of displacement scenarios from an offshore wind development on the birds' time and energy budgets. This initial model is being developed further, by the Centre for Ecology and Hydrology (CEH, UK), to model the energetic and population consequences of a range of levels of displacement from proposed offshore wind energy developments for key species of seabirds breeding at Scottish SPAs and to apply it to the Forth/Tay offshore wind farm development area.

2.3.6.7 Population Modelling

The ultimate test of impact, either for an individual development or cumulatively across multiple developments, is whether there is the likelihood of a decline in population size. There are two spatial scales at which this is relevant: site assessment (for example, in the EU for an SPA), in terms of assessing the effect on meeting the conservation objectives for the site, and effects on the wider biogeographic population. Population models have some utility (Beissinger & Westphal, 1998), but are heavily dependent on the available demographic information, which is variable for different bird species (Maclean *et al.*, 2007). The minimum requirements for running a demographic/population model are generally considered to be the starting population size, productivity, age-dependent survival and age of first breeding. Furthermore, assumptions have to be made that may or may not result in model outcomes that are realistic. Increasingly, population modelling is being applied to proposed offshore wind farms in UK waters, notably in respect of predicted collision mortality. These include several Population Viability Analyses (PVAs) which have been developed recently, or are under development, including those for Sandwich tern on the North Norfolk coast, in relation to the Greater Wash Round 2 proposals, northern gannet at UK and individual SPA levels (WWT Consulting *et al.*, 2012), black-legged kittiwake *Rissa tridactyla*, common guillemot, razorbill, Atlantic puffin *Fratercula arctica* and herring gull *Larus argentatus* in the Forth and Tay region of Scotland (CEH in prep. for Marine Scotland). PVA has become a standard procedure for those species of concern for which demographic variables are available or can be reliably calculated, for example using Integrated Population Modelling to make best use of all available demographic data. A model is also under development by CEH (McDonald *et al.*, 2012) to determine likely energetic and population consequences for breeding common guillemot in the Forth & Tay region of Scotland, using data from the Isle of May. This will provide a useful indication of the level of displacement that may lead to

adverse effects on common guillemot during the breeding season, a time of high energy budgets. Whilst restricted to the breeding season, this model will be informative for the non-breeding season.

Potential Biological Removal (PBR) is a more contentious approach that is less demanding in its data requirements, but makes more assumptions (Niel & Lebreton, 2005; Dillingham & Fletcher, 2008). Its original development for assessing permitted bycatch of marine mammals, and subsequent similar applications for sustainable harvesting of hunting quarry species, required a feedback loop via bag statistics (Taylor *et al.*, 2006). Such a feedback loop, with adjustments to harvesting levels, is not possible where it is used in risk assessments for wind farms and, whilst there has been some application of PBR in relation to wind farms (e.g. Watts, 2010), this approach has substantial limitations. At the very least, the application of PBR requires a range of 'recovery factors' to be tested and input parameters should include a measure of variability where available. Comparison with PVA outputs for a species, where these are available, may provide greater confidence in the applicability of PBR.

2.3.6.8 Post-construction Monitoring

Post construction monitoring needs to mirror pre-construction methods, as detailed in earlier sections, to determine changes that might be attributable to the wind. These changes include shifts in distribution (displacement), changes in abundance or species composition, or changes in behaviour (including flight avoidance). Additional studies of collision mortality will apply to some sites and species. Post-construction monitoring is also needed to determine the effectiveness of any mitigation measures that have been implemented and to validate pre-construction predictions (e.g. collision risk models) and to aid in adaptive management. If published, such studies will contribute to the understanding of interactions between wind farms and birds, thereby reducing uncertainty and providing an improved basis for decisions on further wind farm proposals and recommendations for mitigation.

The duration of post-construction monitoring will depend upon the issues identified by the EIA, but will need to continue for long enough to permit short- and long-term changes to be distinguished. Regular review of post-construction monitoring will enable methods to be refined or monitoring to be discontinued or extended as appropriate to the particular circumstances. For example, the Scottish Government has proposed that post-construction monitoring is undertaken in years 1, 2, 3, 5, 10 and 15 years, at some sites where major habitat change has not occurred (SNH, 2005; 2009a; 2010b). Where major habitat change has taken place (such as tree removal) the recommendation is to monitor in years 3, 6, 9, 12 and 15 (SNH, 2009a). Consistency of methods and the use of standard methods are important to enable comparison before and after construction within sites and comparison of particular factors across sites. It is vital that long-term monitoring is carried out on at least some sites where these offer the best opportunity to advance our understanding and reduce uncertainties.

The establishment of a monitoring and management group may be a useful model, depending on the scale of the project, to agree the scope and methods for post-construction monitoring. In cases where no significant issues arise during the EIA, only limited post-construction monitoring may be required, or possibly none will be needed. The need for post-construction monitoring should be determined at the time of consent and should be proportionate to the scale of the project and its predicted impacts. Strategic research requires partnerships between developers, regulators and other stakeholders.

Guidance documentation on survey and assessment methods is freely available (see *Section on Useful websites, pages and online reports*).

2.4 Integrated Planning Processes

2.4.1 The Benefits of Early and Pro-active Consultation and Joint Working

Conflicts between different groups of stakeholders are a symptom of failures to come together in the processes of developing policy and planning frameworks. Where policy makers, planners, authorities, NGOs, industry groups and researchers all work together in a spirit of openness and

problem solving, the necessary ‘buy in’ and trustful relationships are in place to head off conflicts and ensure successful policy implementation.

NGOs generally welcome opportunities to work with developers and policy-makers to promote biodiversity-friendly wind energy deployment. Often developers will approach BirdLife partners before making a project proposal to find out if there are likely to be significant impacts on birds and other biodiversity. Developers, scientists and government institutions should work pro-actively with relevant stakeholders, including NGOs, to produce guidance documents on sensitive renewables deployment (examples are provided in *Boxes 11-14*).

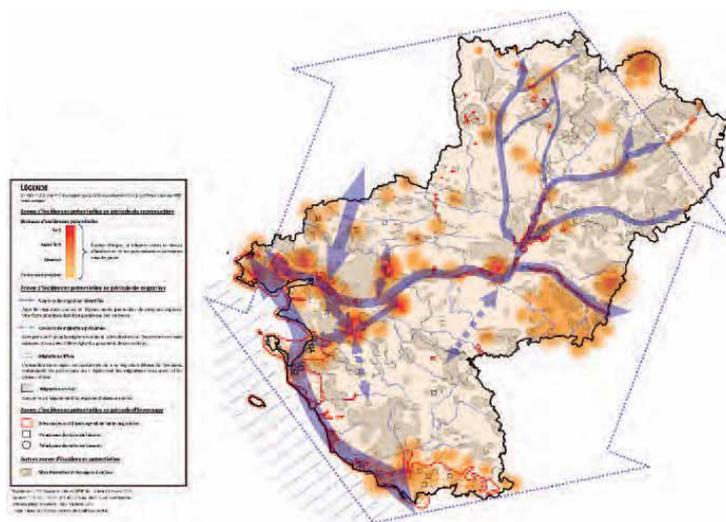
Box 11 - Working between government, industry and NGOs for biodiversity-friendly wind power in France

The French national programme on wind energy and biodiversity, ‘Éolien – Biodiversité’, was created in 2006. It is managed by the French energy agency (ADEME), the ministry of the environment (MEDDLT), and renewable energy professionals (SER-FEE), with overall coordination by LPO/BirdLife France. The programme is based on a set of quality criteria:

- Respect for the ecological sensitivity of development sites, using spatial planning;
- The preservation of biodiversity when building, aiming for no net loss of biodiversity;
- Ecological monitoring for birds and bats during operation, and reduction of impacts found during monitoring; and
- Rehabilitation of the site, taking into account biodiversity.

It aims to give tools to practitioners in order to help them to build nature-friendly wind farms. These tools are: a permanent national resource centre, providing, for example, an up to date bibliography, a dedicated web resource area and online advice; accurate guidelines on EIA and specific surveys; expert advice on specific projects (e.g. R&D, spatial planning, surveys); financial support; and environmental NGO networking and capacity building.

The programme supports regional authorities to prepare regional wind energy schemes, defining zones within which the feed-in tariff will be available. Biodiversity sensitivity maps are used to determine best locations, and to minimize cumulative effects. The data needed for mapping is linked with accurate knowledge on bird diversity, abundance, location and potential sensitivity to wind turbines. The map below is an example of one of the regional maps produced through compilation of all this data.



More information can be found at: www.eolien-biodiversite.com

Another avenue for cooperation between environmental stakeholders and developers is through joint declarations of intent such as the ‘Budapest Declaration’ (*Box 12*) and the Renewables Grid Initiative ‘Declaration on Electricity Network Development and Nature Conservation in Europe’ (*Box 13*).

Box 12 - Budapest Declaration on power lines and bird mortality in Europe

On 13 April 2011, Budapest hosted a special Conference *Power lines and bird mortality in Europe*. This

important event was co-organised by MME/BirdLife Hungary, the Ministry of Rural Development of Hungary and BirdLife Europe, and was kindly hosted by MAVIR (the Hungarian Transmission System Operator Company Ltd.), as part of the official programme of the Hungarian EU Presidency.

The aim of the Conference was to bring together nature conservationists, industry professionals and governments and to stimulate joint actions to address the problem of large-scale bird mortality on power lines at the European level. The Conference was attended by 123 participants from 29 European and Central Asian countries, the European Commission, UNEP-AEWA, six energy and utility companies, experts, businesses and NGOs. The participants adopted a special Declaration calling the European governments and the EU institutions to ensure that the production and transport of our energy (including that from wind energy sources) will not be the cause of unnecessary death of millions of birds.

The declaration calls on the European Commission and national governments “*as they formulate, commit to, and pursue an ambitious set of climate, energy and biodiversity conservation targets and strategies to reconcile energy generation, transmission and distribution with the protection of wild birds within and beyond protected areas*” to

“maintain high levels of implementation of the EU’s environmental acquis including the Birds and the Habitats Directives and relevant international legislation through the application at national or regional level of effective legal, administrative, technical or other requisite measures for: 1) minimisation of the negative impacts of power lines on the natural environment and wild birds and 2) ensuring a system of general protection of wild birds as requested by the Birds Directive, and 3) ensuring that such measures are incorporated in the assessment of investment projects such as the electricity ‘Projects of European Interest’ that will be advanced through the follow-up of the EU’s Energy Infrastructure Package.”

The declaration then calls on all interested parties to jointly undertake a programme of follow up actions leading to effective minimisation of power line-induced bird mortality across the European continent and beyond. The declaration has been endorsed by the Standing Committee to the Bern Convention at its 31st meeting (2011) and the Convention carried out the first monitoring of its implementation in 2013.

Box 13 - The European grid Declaration on Electricity Network Development and Nature Conservation in Europe

The Renewables Grid Initiative (RGI) is a coalition of electricity transmission system operators (TSOs) and green NGOs including BirdLife and WWF. It calls for strong political leadership to ensure that the right grid infrastructure is developed to enable rapid deployment of renewable energy in Europe. The RGI recognises that installing thousands of kilometres of new lines in Europe requires careful planning, so that all stakeholders’ concerns are properly addressed. RGI has facilitated constructive engagement between NGO stakeholders and European transmission system operators to find ways to accelerate development of Europe’s grid infrastructure to accommodate a high share of renewables, while also protecting the natural environment.

The RGI European grid *Declaration on Electricity Network Development and Nature Conservation in Europe* was signed by a large number of grid operators and NGOs in 2011. In this the TSOs commit to taking steps to minimise overall infrastructure needs, and to avoid and minimise impacts on biodiversity. In turn the NGOs commit to constructive working with the TSOs to enable these principles to be applied, in support for the transition to renewable energy in Europe. RGI’s work programmes include a range of initiatives to implement the Declaration’s principles, including publishing good practice guides and applying best practices in grid projects ‘on the ground’.

Legislation, regulations and good practices for biodiversity-friendly wind energy development are not always well-understood by all parties concerned. Moreover institutions often lack the necessary capacity to ensure they are properly applied. The wind energy industry, governments and NGO stakeholders can help build capacity in institutions and developers to improve implementation of law and good practice by providing training and advice (*Box 14*).

Box 14 - Good Practice Wind project

RSPB Scotland/BirdLife UK and the European Wind Energy Association were among the partners in an ambitious project called ‘Good Practice in Wind Energy Development’ (GP Wind) which ran between 2010 and 2012. The project promoted the deployment of appropriately located wind energy development in Europe. Led

by the Scottish Government, and funded by the Intelligent Energy Europe Programme, GP Wind addressed barriers to the development of onshore and offshore wind generation. It identified good practice in two key areas: community engagement and reconciling renewable energy with wider environmental objectives. By bringing together renewables developers (such as ScottishPower Renewables and Scottish and Southern Energy), regional and local government, environmental agencies and NGOs from eight different regions of Europe to share experiences, the project aimed to facilitate the deployment of renewable energy in support of the European 2020 targets.

The main outputs of the project included a good practice guide and 'how to' toolkit. Through active engagement with stakeholders, the GP Wind project partners identified 16 thematic case studies which cover the key environmental and community engagement issues. These case studies include; impacts on species and habitats, carbon accounting, landscape and visual impacts issues, cumulative impact issues, community concerns and community benefits, public perception issues and socio-economic impacts. The case studies form the basis of the good practice. The 'how to' toolkit provides specific information, models and tools which can be adapted for use across Europe. The project website includes a database of information, case study reports, good practice and expertise, and has been maintained beyond the life of the project. More information can be found at: www.project-gpwind.eu.

At project level, developers should start their engagement with relevant stakeholders as early on in the project development process as possible. Although within the EU, EIA procedures will ensure public engagement, by this late formal stage in project development there are great possibilities that issues causing conflict will have already been 'locked' into the project, or will require substantial alteration or mitigation of the project in order for it to obtain development consent. This has significant risk and cost implications for developers and investors.

A much better approach is for developers to engage with relevant nature conservation stakeholders well before these formal consent processes, and ideally at the very embryonic stages of site selection. Specialist stakeholders can give valuable advice on the likelihood of conflicts at different sites, some of which may not be apparent to the developer. They can also give advice on the baseline surveys that may be needed and suitable methodologies for impact assessment. If potential conflicts are identified early in a project development process it is much easier to adapt proposals to avoid or mitigate issues, or if necessary, avoid problematic sites all together.

Adopting such an approach makes development proposals more certain, reduces unnecessary cost and delay, reduces risks of negative publicity and potentially forges long-term progressive relationships between industry and stakeholders to allow wind energy development to flourish alongside nature conservation interests.

2.4.2 Decision Making and Uncertainty

The impact assessment for a wind energy project will inform the decision-making process, in terms of whether consents should be given or not, and in terms of what mitigation, and potentially compensation, should be required as conditions (although in the EU, where Natura 2000 sites will be affected, a separate Appropriate Assessment under the Habitats Directive will direct this decision-making process, see *Section 2.4.3*).

However, even after the data and experience gathered in over twenty years of study and impact assessment of wind energy projects, there will remain cases where there is significant uncertainty about the likely magnitude and significance of a wind energy project's impact on sensitive bird populations. In these situations it is vital that the precautionary principle is applied in decision-making. This requires a considered judgement of whether mitigation measures, applied with post-construction monitoring in an adaptive management framework (see *Section 2.4.4*), will be sufficient to remove risk of significant impacts, or whether consent should be withheld. A key consideration in this decision should be the proven efficacy of mitigation measures and diligent enforcement by the regulator to ensure that they work as planned, or that unforeseen issues are addressed once a wind farm is operational.

However, uncertainty over impact (either due to lack of empirical impact data from previous studies, or due to inadequate baseline data collection for the EIA) and the potential to use adaptive-management in mitigation should not be used as a reason to consent projects in unsuitable, high-risk

locations. It follows that if significant effects on sensitive bird populations cannot be quantified with sufficient certainty by the impact study, there is significant risk that any mitigation measures proposed will not work to remove them, as the nature and scale of the impact is not sufficiently understood. This approach potentially risks key bird populations, and leaves the developer and decision-maker at risk from costs associated with removal of damaging infrastructure.

Box 15 - Planning control to stop the worst proposals: The case of Lewis wind farm in Scotland

In April 2008, Scottish Ministers announced their decision to refuse consent for the proposal by Lewis Wind Power to construct a very large-scale wind farm on the internationally protected peatlands on the Isle of Lewis in the Outer Hebrides. This robust decision by the Scottish Government recognised that there is no need to destroy important natural heritage resources in order to deliver renewable energy developments, which are a key element in the fight against climate change.

The original proposal, launched in 2001, was to build 234 turbines, 105 km of roads, 141 pylons, five rock quarries and a range of other associated works such as cabling and sub-stations. The vast proportion of the proposal was to be built on the Lewis Peatlands Special Protection Area (SPA) designated and protected under European law. The proposal was for one of the biggest wind farms in Europe on one of the most sensitive peatland sites, which has some of the highest densities of breeding birds in the UK.

The developers carried out extensive survey work and, their environmental assessment showed that the site was even more important than had been previously appreciated. With populations of golden eagle, red and black-throated diver, merlin *Falco columbarius*, dunlin *Calidris alpina*, golden plover, greenshank *Tringa nebularia*, corncrake *Crex crex* and migrating whooper swan from Iceland, it was not possible for the developers to redesign their proposal to avoid damaging impacts on either species or habitats.



However, a revised application for 181 turbines was submitted in 2006. The Scottish Government considered and rejected the application, concluding that the impacts were so severe that they would affect the integrity of the designated site and that because there were many alternative solutions to meet wind farm and electricity generation objectives (which were considered by Ministers to be the primary public needs addressed by the proposal), the proposal should not go ahead. In this instance, compensatory measures did not need to be considered as part of the decision-making process (because the development was being refused). However, the decision letter did note that the peatland habitats affected could not be re-created elsewhere in the Western Isles or in Scotland in a location or manner likely to be suitable for the large populations of rare and vulnerable species involved.

The Lewis proposal superimposed over a map of northern Belgium to illustrate its scale

2.4.3 Decision-Making on Projects within the EU Affecting Natura 2000 Sites

Within the EU, wind energy projects that could have a likely significant effect on a Natura 2000 site will need to undergo an Appropriate Assessment ('AA') under the Habitats Directive, the tests of which direct, rather than guide decision-making. The strict tests are set out in Article 6(4) and are intended to make sure any damage permitted to Natura 2000 sites is both unavoidable and necessary in the genuine and overriding public interest. They are about deciding, in the interests of wider society, where the balance lies between the public interest of conserving Europe's biodiversity and other potential public interest(s) provided by a particular plan or project.

These tests on alternative less damaging solutions and imperative reasons of overriding public interest (IROPI) under Article 6(4) are central to ensuring that the Habitats Directive contributes to sustainable development by making damage to Europe's most important wildlife sites a last resort. Where a plan or project is to be consented on the basis of no alternative solutions and IROPI, Article 6(4) then requires compensatory measures to be secured to protect the overall coherence of the Natura 2000 network. Any damage permitted to Natura 2000 sites is therefore fully justified only as a last resort, having exhausted all other options to protect the site in situ.

EIA and AA are separate, but complementary processes with different purposes. Wind energy developers should consider early in project development how the baseline surveys required for both processes can be combined to ensure efficiency. Developers and decision-makers should refer to the European Commission's guidance document 'Wind Energy Developments and Natura 2000' (European Commission, 2010) on how proposals affecting Natura 2000 sites should be assessed and the correct decision-making processes.

2.4.4 Adaptive Management Frameworks

In those cases where it is appropriate to consent wind energy developments with mitigation measures, decision-makers should require monitoring of the efficacy of those measures through post-construction monitoring (as described in *Section 2.3.6.8*). Ideally, an iterative mechanism or 'adaptive management' should be adopted so that if mitigation measures are shown not to be working as predicted, these can be modified and monitored to ensure that impacts are in fact reduced or removed to the required levels. This adaptive management process should be overseen by the regulator, ideally advised by a management group comprising experts representing the developer, government nature advisor (if one exists) and relevant nature conservation stakeholders. For further guidance on this approach see IAIA guidance on 'EIA follow-up' (Morrison-Saunders *et al.*, 2007).

2.4.5 Dissemination of Results

For the continued successful development of the industry it is important that the results of post construction monitoring are published, especially in regards to actual (compared to predicted) impacts or lack of impacts, and the efficacy of any mitigation. This information is vitally important to inform future development projects, especially in their site selection and environmental assessment, and to inform spatial planning frameworks. Regulators should require post construction monitoring (as set out in *Section 2.3.6.8*) and publication of results as a condition of consent. Ideally, national governments or their agencies should hold this information electronically as a public resource.

RECOMMENDATIONS

Many of the recommendations from the original 2003 report '*Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues*' remain applicable. The following recommendations repeat and expand on those in the original report. Implementation of these measures would, in the authors' opinion, facilitate the smooth further development of the wind energy industry in Europe, whilst ensuring the protection of our internationally important bird populations.

1. There is still a need for governments and their advisors, with the assistance of industry, to carry out coordinated and targeted strategic research on the impacts of wind farms on birds, and the efficacy of mitigation measures and to make this information widely available, so as to inform future project development and decision-making, and reduce uncertainties over wind energy impacts.
 - As part of this, regulators should require developers to carry out comparable pre, during and post construction monitoring.
 - Governments and industry should work together in partnership to provide a single web-based resource for this information so that it can be used to inform future research and project development.
 - There remains the need for widespread survey of Europe's offshore environment and the identification and speedy designation of key marine sites for birds. Governments with adjoining sea areas should work cooperatively to address this issue.
 - There is increasing interest in locating wind energy projects in upland forests, especially in Central Europe. Further research is required to identify the effects of these on forest habitats and sensitive forest bird species.
2. Strategic Planning and associated Strategic Environmental Assessment is a key tool for governments to reduce potential conflicts between protected bird populations and wind energy development. This applies both onshore and offshore, and should be a priority for the relevant government bodies. Spatial zoning and site policy criteria, used effectively, can mediate between biodiversity and wind energy interests and ensure that targets are met in both spheres.
 - Sensitivity mapping is a powerful tool to inform locational decisions for wind energy development and should be used by regulators and the industry.
3. Environmental Impact Assessment is the key process to enable informed and transparent decision-making. Regulators need to ensure that all potentially damaging projects undergo EIA, that these EIAs are scoped properly and that there are systems in place to ensure these are undertaken by professionally competent ecologists. Inadequate EIA needs to be challenged by regulators, who should ensure they retain staff that are qualified to understand and critically assess these documents.
 - Cumulative impact assessment continues to be generally poorly addressed in wind energy EIAs in Europe. Regulators should ensure EIAs assess this adequately, and work with academics and industry to support further work to facilitate the development of workable assessment methodologies.
4. Regulators should use the precautionary approach in decision-making when there is significant uncertainty as to the impacts of a wind energy proposal on sensitive bird populations. Although adaptive management in post-construction monitoring and mitigation is a valid approach, it should not be used to justify consent of development in unsuitable locations where key bird populations may be put at risk.
 - Within the EU, there remain significant issues with regulators not properly implementing the tests of Article 6 of the Habitats Directive, where wind energy development is likely to have a significant effect on a Natura 2000 site. National governments and the European Commission should act to ensure training and oversight is provided to address this.

5. Developers should seek to apply an integrated planning approach to project development. A collaborative, open and transparent approach, adopted very early in project development with all relevant stakeholders, has been shown to improve project outcomes, and to reduce costs, delays and uncertainties.
6. Innovative mitigation measures such as increased cut-in speeds and radar-based on-demand shut-down systems should be investigated for inclusion in project proposals when relevant. However, further research is needed into these and other mitigation measures to prove their efficacy.
7. The Standing Committee of the Bern Convention and other relevant Conventions should encourage co-operation between Contracting Parties on migration routes to evaluate cumulative impacts and safeguard key corridors and stop-over sites.

ACKNOWLEDGEMENTS

We would like to thank the following BirdLife partner organisations for their contributions to the report:

BirdWatch Ireland (BWI);
 Bulgarian Society for the Protection of Birds (BSPB);
 Drusvto za Opazovanje in Proučevanje Ptice Slovenije (DOPPS);
 Hellenic Ornithological Society (HOS);
 Ligue pour la Protection des Oiseaux (LPO);
 Lega Italiana Protezione Uccelli (LIPU);
 Magyar Madartani és Természetvédelmi Egyesület (MME);
 Naturschutzbund Deutschland (NABU);
 Natuurpunt;
 Sociedad Española de Ornitología (SEO);
 Societatea Ornitologica Romana (SOR); and
 Sveriges Ornitologiska Forening (SOF)

Many thanks go to Wouter Langhout and Willem Van den Bossche from BirdLife International, for their constructive comments and invaluable assistance in co-ordinating input from other BirdLife partners.

REFERENCES

- ABPmer, Cefas & HR Wallingford (2008) *Review of Round 1 sediment process monitoring data – lessons learnt*. Report of work by ABP Marine Environmental Research Ltd (ABPmer), the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and HR Wallingford, jointly funded by the Department for Energy and Climate Change (DECC) and Department for Environment, Food and Rural Affairs (DEFRA), as part of the package of work overseen by the pan-UK-Government Research Advisory Group (RAG).
- Anderson, R. L., Flint, S. A., Sanders, S. S. & Sterner, D. (2007) *California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development*. California Energy Commission and California Department of Fish and Game. CEC, Sacramento, California, USA.
- Anderson, R., Morrison, M., Sinclair, K. & Strickland, D. (1999) *Studying wind energy/bird interactions: a guidance document. Metrics and methods for determining or monitoring potential impacts on birds at existing and proposed wind energy sites*. Report prepared for the Avian Subcommittee and National Wind Coordinating Committee (NWCC), Washington, D.C., USA.
- Arnett, E. B. (2006) A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities. *Wildlife Society Bulletin*, **34**: 1440-1445

- Band, W. (2012) *Using a collision risk model to assess bird collision risk for offshore windfarms*. Report commissioned by The Crown Estate, through the British Trust for Ornithology, via its Strategic Ornithological Support Services, Project SOSS-02. The Crown Estate, London, UK. http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS02_Band1ModelGuidance.pdf [accessed 04 March 2013].
- Band, W., Madders, M. & Whitfield, D. P. (2005) *Developing field and analytical methods to assess avian collision risk at wind farms*. Birds and Wind Power (Eds. de Lucas, M., Janss, G. F. E. & Ferrer, M.). Lynx Editions, Barcelona.
- Band, W., Madders, M. & Whitfield, D. P. (2007) Developing field and analytical methods to assess avian collision risk at wind farms. In *Birds and wind farms: risk assessment and mitigation* (Eds. de Lucas, M., Janss, G. F. E. & Ferrer, M.), pp. 259-275. Quercus, Madrid, Spain.
- Barrios, L. & Rodriguez, A. (2004) Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology*, **41**: 72-81.
- Barton, J. R. & Pretty, J. (2010) What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environmental Science and Technology*, **44**: 3947-55.
- Batary, P. & Baldi, A. (2004) Evidence of an edge effect on avian nest success. *Conservation Biology*, **18**: 389-400.
- Beissinger, S. R. & Westphal, M. I. (1998) Invited paper on the use of demographic models of population viability in endangered species management. *Journal of Wildlife Management* **62**: 821-841.
- Bellebaum, J., Korner-Nievergelt, F. & Mammen, U. (2012) *Rotmilan und Windenergie in Brandenburg - Auswertung vorhandener Daten und Risikoabschätzung*. Report by ÖKOTOP for the Landesamtes für Umwelt, Gesundheit und Verbraucherschutz, Brandenburg, Germany.
- Bellebaum, J., Korner-Nievergelt, F., Dürr, T. & Mammen, U. (2013) Wind turbine fatalities approach a level of concern in a raptor population. *Journal for Nature Conservation*, in press, available online.
- Bernardino, J., Bispo, R., Costa, H. & Mascarenhas, M. (2013) Estimating bird and bat fatality at wind farms: a practical overview of estimators, their assumptions and limitations *New Zealand Journal of Zoology*, **40**: 63-74.
- Bevanger, K., Berntsen, F., Clausen, S., Dahl, E. L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., Johnsen, L., Kvaløy, P., Lund-Hoel, P., May, R., Nygård, T., Pedersen, H. C., Reitan, O., Røskoft, E., Steinheim, Y., Stokke, B. & Vang, R. (2010) *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (Bird-Wind)*. Report on findings 2007-2010. Norwegian Institute for Nature Research (NINA), Trondheim, Norway.
- Bibby, C. J., Burgess, N. D. & Hill, D. A. (1992) *Bird Census Techniques*. British Trust for Ornithology and the Royal Society for the Protection of Birds. Academic Press, London.
- Bibby, C. J., Phillips, B. N. & Seddon, A. J. E. (1985) Birds of restocked conifer plantations in Wales. *Journal of Applied Ecology*, **22**: 619-633.
- Biosis Research (2003) *Avian Modelling Addendum to Timewell and Meredith 2002*. Appendix 6a, Biosis Research report for the Hydro-Electric Company. Melbourne, Australia.
- BirdLife International (2004) *Birds in the European Union: a status assessment*. BirdLife International, Wageningen, The Netherlands. http://www.birdlife.org/action/science/species/birds_in_europe/birds_in%20the_eu.pdf [accessed 30 July 2013].
- BirdLife International (2011) *Meeting Europe's Renewable Energy Targets in Harmony with Nature*. (Eds. Scrase, I. & Gove, B.) BirdLife Europe, RSPB (Royal Society for the Protection of Birds), Sandy, UK.

- Bispo, R., Bernardino, J., Marques, T. A. & Pestana, D. (2012) Modeling carcass removal time for avian mortality assessment in wind farms using survival analysis. *Environmental and Ecological Statistics*, **20**(1): 1-19.
- Bordan, D., Jancar, T. & Mihelic, T. (2012) *Bird Sensitivity Map for the Placement of Wind Farms in Slovenia*. DOPPS/BirdLife Slovenia, Slovenia. http://www.ptice.si/index.php?option=com_content&task=view&id=425&Itemid=15 [accessed 30 July 2013].
- Brown, A. F., & Shepherd, K. B. (1993). A method for censusing upland breeding waders. *Bird Study*, **40**(3): 189-195.
- Bright, J., Langston, R. H. W. & Anthony, S. (2009) *Mapped and written guidance in relation to birds and onshore wind energy development in England*. RSPB, Sandy, UK.
- Bright, J., Langston, R., Bullman, R., Evans, R., Gardner, S. & Pearce-Higgins, J. (2008) Map of bird sensitivities to wind farms in Scotland: A tool to aid planning and conservation. *Biological Conservation*, **141**: 2342-2356.
- Bright, J. A., Langston, R. H. W., Bullman, R., Evans, R., Gardner, S., Pearce-Higgins, J. & Wilson, E. (2006) *Bird sensitivity map to provide locational guidance for onshore wind farms in Scotland*. RSPB Research Report no. 20, as part of a programme of work jointly funded by the RSPB and Scottish Natural Heritage (SNH). RSPB, Sandy, UK.
- Buckland, S. T., Burt, M. L., Rexstad, E. A., Mellor, M., Williams, A. E. & Woodward, R. (2012) Aerial surveys of seabirds: the advent of digital methods. *Journal of Applied Ecology*, **49**: 960-967.
- Byrkjedal, I., & Thompson, D. B. (1998) *Tundra plovers: the Eurasian, Pacific and American golden plovers and grey plover*. Academic Press, USA. ISBN: 9780856611094.
- Calladine, J., Garner, G., Wernham, C., & Buxton, N. (2010) Variation in the diurnal activity of breeding Short-eared Owls *Asio flammeus*: implications for their survey and monitoring, *Bird Study*, **57**(1): 89-99.
- Camphuysen, C. J., Fox, A. D., Leopold, M. F. & Petersen, K. (2004) *Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the UK*. COWRIE Ltd., London, UK.
- Carrete, M., Sánchez-Zapata, J. A., Benítez, J. R., Lobón, M. & Donázar, J. A. (2009) Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. *Biological Conservation*, **142**: 2954-2961.
- CBD (2006) *COP 8 Decision VIII/28 - Impact assessment: Voluntary guidelines on biodiversity-inclusive impact assessment*. Convention on Biological Diversity. <http://www.cbd.int/decision/cop/?id=11042> [accessed 30 July 2013].
- CFPA Europe (2010) *European guidelines: Wind turbines fire protection guideline*. Guideline no. 22:2010 F, VdS Schadenverhütung (author: Rusch, H.) report prepared for the Confederation of Fire Protection Associations in Europe (CFPA E), Germany.
- Chamberlain, D. E., Freeman, S. N., Rehfisch, M. R., Fox, A. D. & Desholm, M. (2005) *Appraisal of Scottish Natural Heritage's Wind Farm Collision Risk Model and its Application*. BTO Research Report 401 under contract to English Nature. British Trust for Ornithology, Thetford, UK.
- Chamberlain, D. E., Rehfisch, M. M., Fox, A. D., Desholm, M. & Anthony, S. J. (2006) The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. In *Wind, Fire and Water: Renewable Energy and Birds*, Proceedings of the British Ornithologists' Union Conference (BOU), 1-3 April 2005, University of Leicester, UK. *Ibis*, **148**(Suppl. 1): 198-202.
- Collier, M. P., Dirksen, S. & Krijgsveld, K. L. (2011) *A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines. Part 1: Review*. Report commissioned by

- The Crown Estate, through the British Trust for Ornithology, via its Strategic Ornithological Support Services, Project SOSS-03A, Part 1. Bureau Waardenburg report no. 11-078, Culemborg, The Netherlands.
http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS03A_Part1.pdf
[accessed 30 July 2013].
- Collier, M. P., Dirksen, S. & Krijgsveld, K. L. (2012) *A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines. Part 2: Feasibility study of systems to monitor collisions*. Report commissioned by The Crown Estate, through the British Trust for Ornithology, via its Strategic Ornithological Support Services, Project SOSS-03A, Part 2. Bureau Waardenburg report no. 11-215, Culemborg, The Netherlands.
http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS03A_Part2.pdf
[accessed 30 July 2013].
- Cook, A. S. C. P., Johnston, A., Wright, L. J. & Burton, N. H. K. (2012) *A review of flight heights and avoidance rates of birds in relation to offshore wind farms*. BTO Research Report no. 618, on behalf of The Crown Estate, as part of its Strategic Ornithological Support Services. The British Trust for Ornithology, Thetford, UK.
http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS02_BTORevie_w.pdf [accessed 07 Jan 2013].
- Cook, A. S. C. P., Ross-Smith, V. H., Roos, S., Burton, N. H. K., Beale, N., Coleman, C., Daniel, H., Fitzpatrick, S., Rankin, E., Norman, K. & Martin, G. (2011) *Identifying a Range of Options to Prevent or Reduce Avian Collision with Offshore Wind Farms using a UK-Based Case Study*. BTO Research Report no. 580. The British Trust for Ornithology, AEA Group, the Met Office and the University of Birmingham Centre for Ornithology under contract to the Department of Environment, Food and Rural Affairs (DEFRA). Thetford, UK.
- Dahl, E. L., Bevanger, K., Nygård, T., Røskaft, E. & Stokke, B. G. (2012) Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement. *Biological Conservation*, **145**: 79-85.
- Dawson, D. K. & Efford, M. G. (2009) Bird population density estimated from acoustic signals. *Journal of Applied Ecology*, **46**: 1201-1209.
- Degraer, S., Brabant, R. & Rumes, B. (2012) *Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts*. pp. 155 pp. + annexes. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit, Brussels, Belgium.
- de Lucas, M., Ferrer, M., Bechard, M. J. & Munoz, A. R. (2012) Griffon vulture mortality at wind farms in southern Spain: Distribution of fatalities and active mitigation measures. *Biological Conservation*, **147**: 184-189.
- de Lucas, M., Janss, G. F. E., Whitfield, D. P. & Ferrer, M. (2008) Collision fatality of raptors in wind farms does not depend on raptor abundance. *Journal of Applied Ecology*, **45**(6): 1695-1703.
- Desholm, M. (2005) *TADS investigations of avian collision risk at Nysted offshore wind farm, autumn 2004*. Energi E2, National Environmental Research Institute, Ministry of the Environment, Copenhagen, Denmark.
- Desholm, M. (2009) Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. *Journal of Environmental Management*, **90**: 2672-2679.
- Desholm, M. & Kahlert, J. (2005) Avian collision risk at an offshore wind farm. *Biology Letters*, **1**(3): 296-298.
- Devereux, C. L., Denny, M. J. H. & Whittingham, M. J. (2008) Minimal effects of wind turbines on the distribution of wintering farmland birds. *Journal of Applied Ecology*, **45**: 1689-1694.
- Diaz, S., Fargione, J., Chapin, F. S. & Tilman, D. (2006) Biodiversity loss threatens human well-being. *Plos Biology*, **4**: 1300-5.

- Dillingham, P. W. & Fletcher, D. (2008) Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationships. *Biological Conservation*, **141**: 1783–1792.
- Dimalexis, A., Kastritis, T., Manolopoulos, A., Korbeti, M., Fric, J., Saravia Mullin, V., Xirouchakis, S. & Bousbouras, D. (2010) *Identification and mapping of sensitive bird areas to wind farm development in Greece*. Hellenic Ornithological Society, Athens, Greece. 126 pages. <http://files.ornithologiki.gr/docs/politiki/aiolika/prosdiorismos%20kai%20xartografisi.pdf> [accessed 30 July 2013].
- Dirksen, S. & van der Winden, J. (1998) Nocturnal collision risks of birds with wind turbines in tidal and semi-offshore areas. In *Wind energy and landscape* (Eds. Ratto, C. F. & Solari, G.), pages 99-108. Balkema, Rotterdam, The Netherlands.
- Dooling, R. (2002) *Avian hearing and the avoidance of wind turbines*. National Renewable Energy Laboratory, Golden, CO, USA.
- Douglas, D. J. T., Follestad, A., Langston, R. H. W. & Pearce-Higgins, J. W. (2012) Modelled sensitivity of avian collision rate at wind turbines varies with number of hours of flight activity input data. *Ibis*, **154**: 858-861.
- Drewitt, A. L. & Langston, R. H. W. (2006) Assessing the impacts of wind farms on birds. *Ibis*, **148**: 29-42.
- Drewitt, A. L. & Langston, R. H. W. (2008) Collision effects of wind-power generators and other obstacles on birds. *Annals of the New York Academy of Sciences*, **1134**: 233-266.
- Dudley, S. P., Gee, M., Kehoe, C., Melling, T. M. & The British Ornithologists' Union Records Committee (BOURC) (2006) *The British List: A Checklist of Birds of Britain* (7th edition). *Ibis*, **148**: 526-563.
- Duffy, K. & Steward, M. (2008) *Turbine search methods and carcass removal trials at the Braes of Doune wind farm*. Natural Research Information Note 4. Natural Research Ltd., Banchory, Scotland.
- EEA (2009) *Europe's onshore and offshore wind energy potential. An assessment of environmental and economic constraints*. European Environment Agency, Copenhagen, Denmark.
- Efford, M. G., Dawson, D. K. & Borchers, D. L. (2009) Population density estimated from locations of individuals on a passive detector array. *Ecology*, **90**: 2676-2682.
- Eichhorn, M., Johst, K., Seppelt, R. & Drechsler, M. (2012) Model-based estimation of collision risks of predatory birds with wind turbines. *Ecology and Society*, **17**(2): 1.
- Erickson, W., Young, D., Johnson, G., Jeffrey, J., Bay, K., Good, R. & Sawyer, H. (2003) *Wildlife Baseline Study for the Wild Horse Wind Project. Summary of Results from 2002 to 2003 Wildlife Surveys*. Report by WEST Inc. prepared for Zilkha Renewable Energy, Portland, Oregon, USA.
- European Commission (2001) *Guidance on EIA: Scoping*. Prepared by Environmental Resources Management Ltd. <http://ec.europa.eu/environment/eia/eia-guidelines/g-scoping-full-text.pdf>, see also other EC guidance documents on EIA :- <http://ec.europa.eu/environment/eia/eia-support.htm> [accessed 30 July 2013].
- European Commission (2010) *Wind energy developments and Natura 2000. Wind energy development in accordance with the EU nature legislation*. This document has been prepared with the assistance of Ecosystems Ltd. (part of the N2K Group EEIG) under contract to the European Commission (contract N° 070307/2008/513837/SER/B2). Council of Europe, Brussels, Belgium.
- Everaert, J. & Kuijken, E. (2007) *Wind turbines and birds in Flanders (Belgium): Preliminary summary of the mortality research results*. Research Institute for Nature and Forest (INBO), Brussels, Belgium.
- Everaert, J. E. & Stienen, W. M. (2007) Impact of wind turbines on birds in Zeebrugge (Belgium): significant effect on breeding tern colony due to collisions. *Biodiversity and Conservation*, **16**:

3345-3359.

- EWEA (2013) *Wind in Power: 2012 European Statistics*. European Wind Energy Agency, Brussels, Belgium.
http://www.ewea.org/fileadmin/files/library/publications/statistics/Wind_in_power_annual_statistics_2012.pdf [accessed 29 April 2013].
- Exo, K.-M., Hüppop, O. & Garthe, S. (2003) Birds and offshore wind farms: a hot topic in marine ecology. *Wader Study Group Bulletin*, **100**: 50-53
- Farfán, M., Vargas, J., Duarte, J. & Real, R. (2009) What is the impact of wind farms on birds? A case study in southern Spain. *Biodiversity and Conservation*, **18**(14).
- Fernley, J., Lowther, S. & Whitfield, D. P. (2006) *A Review of Goose Collisions at Operating Wind Farms and Estimation of the Goose Avoidance Rate*. Unpublished Report. West Coast Energy Developments Ltd, Mold, UK.
- Ferrer, M., de Lucas, M., Janss, G. F. E., Casado, E., Munoz, A. R., Bechard, M. J. & Calabuig, C. P. (2012) Weak relationship between risk assessment studies and recorded mortality in wind farms *Journal of Applied Ecology*, **49**: 38-46.
- Fox, A. D., Desholm, M., Kahlert, J., Christensen, T. K. & Krag Petersen, I. B. (2006) Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. *Ibis*, **148**: 129-144.
- Furness, R. & Wade, H. (2012) *Vulnerability of Scottish seabirds to offshore wind turbines*. MacArthur Green report, commissioned by Marine Scotland, Glasgow, Scotland.
- Furness, R. W., Wade, H. M. & Masden, E. A. (2013) Assessing vulnerability of marine bird populations to offshore wind farms. *Journal of Environmental Management*, **119**: 55-66.
- Garthe, S. & Hüppop, O. (2004) Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. *Journal of Applied Ecology*, **41**: 724-734.
- Garvin, J. C., Jennelle, C. S., Drake, D. & Grodsky, S. M. (2011) Response of raptors to a windfarm. *Journal of Applied Ecology*, **48**: 199-209.
- Gilbert, G., Gibbons, D. W. & Evans, J. (1998) *Bird Monitoring Methods*. RSPB, BTO, WWT, JNCC, ITE & The Seabird Group, Sandy, UK.
- Gill, J. A., Norris, K. & Sutherland, W. J. (2001) Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation*, **97**: 265-268.
- Griffin, L., Rees, E. & Hughes, B. (2010) *The migration of whooper swans in relation to offshore wind farms*. Final Report to COWRIE Project Code: SWAN-06-08, London, UK.
- Grünkorn, T., Diederichs, A., Poszig, D., Diederichs, B. & Nehls, G. (2009) Wie viele Vögel kollidieren mit Windenergieanlagen? *Natur und Landschaft*, **84**: 309-314.
- GWEC (2013) *Global Wind Report: Annual Market Update 2012*. Global Wind Energy Council, Brussels, Belgium.
http://www.gwec.net/wp-content/uploads/2012/06/Annual_report_2012_LowRes.pdf [accessed 29 April 2013].
- Haas, D., Nipkow, M., Fiedler, G., Schneider, R., Haas, W. & Schürenberg, B. (2005) *Protecting birds on powerlines: A practical guide on the risks to birds from electricity transmission facilities and how to minimise any such adverse effects*. On behalf of NABU - German Society for Nature Conservation, Bonn, Germany.
- Hardey, J., Humphrey, Q. P. C., Wernham, C. V., Riley, H. T., Etheridge, B. & Thompson, D. B. A. (2009) *Raptors: a field guide to survey and monitoring*, 2nd edition. The Stationary Office, Edinburgh, Scotland.
- Hartman, J. C., Krijgsveld, K. L., Poot, M. J. M., Fijn, R. C., Leopold, M. F. & Dirksen, S. (2012) *Effects on birds of Offshore Wind farm Egmond aan Zee (OWEZ). An overview and integration*

- of insights obtained.* Bureau Waardenburg bv commissioned by NoordzeeWind, Culemborg, The Netherlands.
- Heath, M. F. & Evans, M. I. (Eds.) (2000) *Important bird areas in Europe: priority sites for conservation: 1. Northern Europe.* Birdlife Conservation Series, 8 Birdlife International, Cambridge, UK. ISBN 0-946888-34-5.
- Henderson, I. G., Langston, R. H. W. & Clark, N. A. (1996) The response of common terns *Sterna hirundo* to power lines: an assessment of risk in relation to breeding commitment, age and wind speed. *Biological Conservation*, **77**: 185-192.
- Hodos, W., Potocki, A., Storm, T. & Gaffney, M. (2001) *Reduction of motion smear to reduce avian collisions with wind turbines.* National Avian-Wind Power Planning Meeting IV, pp. 88-105.
- Hoekstra, J. M., Boucher, T. M., Ricketts, T. H. & Roberts, C. (2005) Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters*, **8**: 23-29.
- Hötker, H., Thomsen, K.-M. & Jeromin, H. (2006) *Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats - facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation.* Michael-Otto-Institut im NABU, Bergenhusen, Germany.
- Huddleston, J. (ed.) (2010) *Understanding the Environmental Impacts of Offshore Windfarms.* COWRIE. Information Press, Oxford, UK.
- Huntley, B. (2007) *Climatic change and the conservation of European biodiversity: Towards the development of adaptation strategies.* Report for the Bern Convention Standing Committee T-PVS/Inf (2007) 3. Institute of Ecosystem Science, School of Biological and Biomedical Sciences, Durham University, Durham, UK. <https://wcd.coe.int/com.instranet.InstraServlet?command=com.instranet.CmdBlobGet&InstranetImage=1574437&SecMode=1&DocId=1438656&Usage=2> [accessed 30 July 2013].
- Huntley, B., Collingham, Y. C., Green, R. E., Hilton, G. M., Rahbek, C. & Willis, S. G. (2006) Potential impacts of climatic change upon geographical distributions of birds. In *Wind, Fire and Water: Renewable Energy and Birds.* Proceedings of the BOU Conference, University of Leicester, 1-3 April 2005. *Ibis*, **148** (Suppl. 1): 8-28.
- Huntley, B., Green, R. E., Collingham, Y. C., & Willis, S. G. (2007) *A Climatic Atlas of European Breeding Birds.* Published as a partnership between Durham University, the RSPB and Lynx Edicions in association with the University of Cambridge, BirdLife International and EBCC. Lynx Edicions, Barcelona, Spain.
- Huso, M. M. P. (2010) An estimator of wildlife fatality from observed carcasses. *Environmetrics*, **22**: 318-329.
- Icanberry, J. (1991) *Reducing bird-power line collisions.* R & D Program Research Results (August). Pacific Gas and Electric, San Ramon, California, USA.
- IEEM (2006) *Guidelines for Ecological Impact Assessment in the United Kingdom.* Institute of Ecology and Environmental Management, UK. http://www.cieem.net/data/files/Resource_Library/Technical_Guidance_Series/EcIA_Guidelines/TGSEcIA-EcIA_Guidelines-Terrestrial_Freshwater_Coastal.pdf [accessed 30 July 2013].
- Jakle, A. (2012) *Wind Development and Wildlife Mitigation in Wyoming: A Primer.* Ruckelshaus Institute of Environment and Natural Resources, Laramie, Wyoming, USA.
- Janss, G. (2000) *Bird Behavior In and Near a Wind Farm at Tarifa, Spain: Management Considerations.* National Avian – Wind Power Planning Meeting III, pp. 111-114.
- Jenkins, G., Perry, M. & Prior, J. (2009) *The climate of the UK and recent trends.* UK Climate Projections, Met Office Hadley Centre report to Department of Environment, Food and Rural Affairs (DEFRA), London, UK.

- Katzner, T. E., Brandes, D., Miller, T., Lanzone, M., Maisonneuve, C., Tremblay, J. A., Mulvihill, R. & Merovich, G. T. (2012) Topography drives migratory flight altitude of golden eagles: implications for on-shore wind energy development. *Journal of Applied Ecology*, **49**: 1178-1186.
- Kershaw, P., Birchenough, S., Judd, A., Freeman, S. & Wood, D. (2012) *Evaluation of the current state of knowledge on potential cumulative effects from offshore wind farms (OWF) to inform marine planning and licensing*. Cefas (Centre for Environment, Fisheries & Aquaculture Science) report to MMO, Lowestoft, Suffolk, UK.
- King, S., Maclean, I., Norman, T. & Prior, A. (2009) *Developing guidance on ornithological cumulative impact assessment for offshore wind farm developers*. COWRIE Ltd, London, UK.
- Korner-Nievergelt, F., Korner-Nievergelt, P., Behr, O., Niermann, I., Brinkmann, R. & Hellriegel, B. (2011) A new method to determine bird and bat fatality at wind energy turbines from carcass searches. *Wildlife Biology*, **15**: 350-363.
- Korpimäki, E. & Norrdahl, K. (1991) Numerical and functional responses of kestrels, short-eared owl and long-eared owls to vole densities. *Ecology*, **72**: 814-826.
- Kowallik, C. & Borbach-Jaene, J. (2001) Windräder als Vogelscheuchen? – Über den Einfluss der Windkraftnutzung in Gänsestgebieten an der nordwest-deutschen Küste. *Vogelkdl. Ber. Niedersachs.*, **33**: 97-102.
- Krijgsveld, K. L., Akershoek, K., Schenk, F., Dijk, F. & Dirksen, S. (2009) Collision risk of birds with modern large wind turbines. *Ardea*, **97**: 357-366.
- Krijgsveld, K. L., Fijn, R. C., Japink, M., van Horssen, P. W., Heunks, C., Collier, M. P., Poot, M. J. M., Beuker, D. & Dirksen, S. (2011) *Effect studies offshore wind farm Egmond aan Zee. Final report on fluxes, flight altitudes and behavior of flying birds*. Report commissioned by Noordzee Wind OWEZ_R_231_T1_20111114_flux&flight. Bureau Waardenburg report no. 10-219. Bureau Waardenburg bv, Culemborg, The Netherlands.
- Kruckenbergh, H. & Jaene, J. (1999) Zum Einfluss eines Windparks auf die Verteilung weidender Bläßgänse im Rheiderland (Landkreis Leer, Niedersachsen). [The effect of a group of wind turbines on a staging area of white-fronted geese (*Anser albifrons*)] *Natur und Landschaft*, **74**: 420-427.
- Langston, R. H. W. (2010) *Offshore wind farms and birds: round 3 zones, extensions to round 1 and round 2 sites and Scottish Territorial Waters*. RSPB Research Report no. 39, RSPB, Sandy, UK.
- Langston, R. H. W. (2013) Birds and wind projects across the pond: A UK perspective. *Wildlife Society Bulletin*, **37**: 5-18.
- Langston, R. H. W. & Pullan, J. D. (2003) *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 International on behalf of the Bern Convention, RSPB/BirdLife in the UK, Sandy, UK.
- Larsen, J. K. & Guillemette, M. (2007) Effects of wind turbines on flight behaviour of wintering common eiders: implications for habitat use and collision risk. *Journal of Applied Ecology*, **44**: 516-522.
- Larsen, J. K. & Madsen, J. (2000) Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): A landscape perspective. *Landscape Ecology*, **15**: 755-764.
- Leddy, K. L., Higgins, K. F. & Naugle, D. E. (1999) Effects of wind turbines on upland nesting birds in Conservation Reserve Program grasslands. *Wilson Bulletin*, **111**: 100-104.
- Lekuona, J. M. & Ursúa, C. (2007) Avian mortality in wind power plants of Navarra (northern Spain). In *Birds and Wind Power* (Eds. De Lucas, M., Janss, G. & Ferrer, M.), pp. 177-192. Lynx Editions, Barcelona, Spain.

- Leopold, M. F., Dijkman, E. M., Teal, L. & the OWEZ-team (2011) *Local birds in and around the Offshore Wind Farm Egmond aan Zee (OWEZ) (T-0 & T-1, 2002-2010)*. NoordzeeWind report OWEZ_R_221_T1_20110915_localbirds_final. Imares/NoordzeeWind, Wageningen/Ijmuiden, The Netherlands.
- Lindeboom, H. J., Kouwenhoven, H. J., Bergman, M. J. N., Bouma, S., Brasseur, S., Daan, R., Fijn, R. C., de Haan, D., Dirksen, S., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K. L., Leopold, M. & Scheidat, M. (2011) Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. *Environmental Research Letters*, **6**: 035101.
- Lindsay, R. & Bragg, O. (2005) *Wind Farms And Blanket Peat. The Bog Slide of 16th October 2003 at Derrybrien, Co. Galway, Ireland*. University of East London, London, UK.
- Louzao, M., Becares, J., Rodriguez, B., Hyrenbach, K. D., Ruiz, A. & Arcos, J. M. (2009) Combining vessel-based surveys and tracking data to identify key marine areas for seabirds. *Marine Ecology Progress Series*, **391**: 183-197.
- Maclean, I. M. D., Frederiksen, M. & Rehfish, M. M. (2007) *Potential use of population viability analysis to assess the impact of offshore windfarms on bird populations*. COWRIE PVA-03-07, BTO report commissioned by COWRIE Ltd., Thetford, UK.
- Maclean, I. M. D., Rehfish, M. M., Skov, H. & Thaxter, C. B. (2013) Evaluating the statistical power of detecting changes in the abundance of seabirds at sea. *Ibis*, **155**: 113-126.
- Maclean, I. M. D., Skov, H., Rehfish, M. M. & Piper, W. (2006) *Use of aerial surveys to detect bird displacement by offshore windfarms*. COWRIE-DISP-03-2006, BTO Research Report no. 446, commissioned by COWRIE Ltd., London, UK.
- Madders, M. & Whitfield, D. P. (2006) Upland raptors and the assessment of wind farm impacts. *Ibis*, **148**: 43-56.
- Madsen, J. (1995) Impacts of disturbance on migratory waterfowl. *Ibis*, **137**: S67-S74.
- Madsen, J. & Boertmann, D. (2008) Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. *Landscape Ecology*, **23**: 1007-1011
- Martin, G. R., Portugal, S. J. & Murn, C. P. (2012) Visual fields, foraging and collision vulnerability in *Gyps* vultures. *Ibis*, **154**: 626-631.
- Masden, E. A., Fox, A. D., Furness, R. W., Bullman, R. & Haydon, D. T. (2009a) Cumulative impact assessments and bird/wind farm interactions: developing a conceptual framework. *Environmental Impact Assessment Review*, **30**: 1-7.
- Masden, E. A., Haydon, D. T., Fox, A. D. & Furness, R. W. (2010) Barriers to movement: Modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. *Marine Pollution Bulletin*, **60**: 1085-1091.
- Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W., Bullman, R. & Desholm, M. (2009b) Barriers to movement: impacts of wind farms on migrating birds. *ICES Journal of Marine Science*, **66**: 746-753.
- Masden, E. A., Reeve, R., Desholm, M., Fox, A. D., Furness, R. W. & Haydon, D. T. (2012) Assessing the impact of marine wind farms on birds through movement modelling. *Journal of The Royal Society Interface*.
- Mathews, F., Swindells, M., Goodhead, R., August, T. A., Hardman, P., Linton, D. M. & Hosken, D. J. (2013) Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: A blinded randomized trial. *Wildlife Society Bulletin*, **37**: 34-40.
- May, R., Hoel, P. L., Langston, R., Dahl, E. L., Bevanger, K., Reitan, O., Nygård, T., Pedersen, H. C., Røskoft, E. & Stokke, B. G. (2010) *Collision risk in white-tailed eagles: modelling collision risk using vantage point observations in Smøla wind-power plant*. NINA Report 639, Norwegian Institute for Nature Research, Trondheim, Norway.

- McDonald, C., Searle, K., Wanless, S. & Daunt, F. (2012) *Effects of displacement from marine renewable development on seabirds breeding at SPAs: A proof of concept model of common guillemots breeding on the Isle of May*. Final report to MSS. CEH Edinburgh, Edinburgh, UK.
- McGrady, M. J., McLeod, D. R., Petty, S. J., Grant, J. R. & Bainbridge, I. P. (1997) *Golden Eagles and Forestry*. Forestry Commission Research Information Note 292, Roslin, UK.
- McLeod, D. R. A., Whitfield, D. P. & McGrady, M. J. (2002) Improving prediction of Golden Eagle (*Aquila chrysaetos*) ranging in western Scotland using GIS and terrain modelling. *Journal of Raptor Research*, **36**: 70-77.
- Mendel, B., Sonntag, N., Wahl, J., Schwemmer, P., Dries, H., Guse, N., Müller, S. & Garthe, S. (2008) *Profiles of seabirds and waterbirds of the German North and Baltic Seas. Distribution, ecology and sensitivities to human activities within the marine environment*. Naturschutz und Biologische Vielfalt 61. Bundesamt für Naturschutz, Bonn - Bad Godesberg, Germany.
- Minderman, J., Pendlebury, C. J., Pearce-Higgins, J. W. & Park, K. J. (2012) Experimental evidence for the effect of small wind turbine proximity and operation on bird and bat activity. *PLoS ONE*, **7**: e41177.
- Morrison-Saunders, A., Marshall, R. & Arts, J. (2007) *EIA Follow-Up International Best Practice Principles*. Special Publication Series No. 6, International Association for Impact Assessment (IAIA), Fargo, USA. <http://www.iaia.org/publicdocuments/special-publications/SP6.pdf> [accessed 30 July 2013].
- Murphy, J., Sexton, D., Jenkins, G., Boorman, P., Booth, B., Brown, K., Clark, R., Collins, M., Harris, G. & Kendon, L. (2009) *Climate change projections*. Met Office Hadley Centre Report to the Department of Environment, Food and Rural Affairs (Defra), London, UK.
- NE (2010) *Assessing the Effects of Onshore Wind Farms on Birds*. Natural England Technical Information Note TIN069, first edition 7th January 2010. London, UK.
- Negro, J. J. (2011) The ghost fraction of populations: a taxon-dependent problem. *Animal Conservation*, **14**: 338-339.
- Newton, I. (2007) Weather-related mass-mortality events in migrants. *Ibis*, **149**: 453-467.
- Newton, I. & Little, B. (2009) Assessment of wind-farm and other bird casualties from carcasses found on a Northumbrian beach over an 11-year period. *Bird Study*, **56**: 158-167.
- Niel, C. & Lebreton, J.-D. (2005) Using demographic invariants to detect overharvested bird populations from incomplete data. *Conservation Biology*, **19**: 826-835.
- Obermeyer, B., Manes, R., Kiesecker, J., Fargione, J. & Sochi, K. (2012) Development by design: Mitigating wind development's impacts on wildlife in Kansas. *PLoS ONE*, **6**: e26698.
- Orloff, S., & Flannery, A. (1992) *Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County Wind Resource Areas: 1989–1991*. Report to California Energy Commission, Sacramento, CA, USA.
- Pandley, A. J., Hermence, R. & Harness, R. (2007) *Development of a cost-effective system to monitor wind turbines for bird and bat collisions – Phase 1: Sensor system feasibility study*. California Energy Commission Report number CEC-500-2007-004, CEC, Sacramento, California, USA.
- Park, K. J., Turner, A. & Minderman, J. (2013) Integrating applied ecology and planning policy: the case of micro-turbines and wildlife conservation. *Journal of Applied Ecology*, **50**: 199-204.
- Pearce-Higgins, J. W., Stephen, L., Douse, A. & Langston, R. H. W. (2012) Greater impacts of wind farms on bird populations during construction than subsequent operation: results of a multi-site and multi-species analysis. *Journal of Applied Ecology*, **49**: 386-394.
- Pearce-Higgins, J. W., Stephen, L. H., Langston, R. H. W., Bainbridge, I. P. & Bullman, R. (2009) The distribution of breeding birds around upland wind farms. *Journal of Applied Ecology*, **46**: 1323-1331.

- Pedersen, M. B. & Poulsen, E. (1991) *Impact of a 90m/2MW wind turbine on birds. Avian responses to the implementation of the Tjareborg Wind Turbine at the Danish Wadden Sea*. Dansk Viltundersogelser, Denmark.
- Pendlebury, C. (2006) *An Appraisal of "A Review of Goose Collisions at Operating Wind Farms and Estimation of the Goose Avoidance Rate" by Fernley, J., Lowther, S. and Whitfield, P.* British Trust for Ornithology, Thetford, UK.
- Pennycuik, C. J. (1989) *Bird Flight Performance*. Oxford University Press, Oxford, UK.
- Pennycuik, C. J., Bradbury, T. A. M., Einarsson, O. & Owen, M. (1999) Response to weather and light conditions of migrating Whooper Swans *Cygnus Cygnus* and flying height profiles, observed with the Argos satellite system. *Ibis*, **141**: 434-443.
- Percival, S. (2010) *Kentish Flats Offshore Wind Farm: diver surveys 2009-10*. Ecology Consulting report commissioned by Vattenfall Wind Power, Durham, UK.
- Petersen, I. K., Christensen, T. K., Kahlert, J., Desholm, M. & Fox., A. D. (2006) *Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark*. National Environmental Research Institute report to DONG Energy and Vattenfall A/S, University of Aarhus, Denmark.
- Petersen, I. K., & Fox, A. D. (2007) *Changes in bird habitat utilisation around the Horns Rev 1 offshore wind farm, with particular emphasis on Common Scoter*. National Environmental Research Institute report commissioned by Vattenfall A/S, University of Aarhus, Denmark.
- Pettersson, J. (2005) *The impact of offshore wind farms on bird life in southern Kalmar Sound, Sweden. A final report based on studies 1999-2003*. Report to the Swedish Energy Agency, Eskilstuna, Sweden. ISBN 91-631-6878-2.
- Plonczkier, P. & Simms, I. C. (2012) Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. *Journal of Applied Ecology*, **49**: 1187-1194.
- Podolsky, R. (2003) *Avian Risk of Collision (ARC) Model*. NWCC Biological Significance Workshop, 17-18 November 2003, National Wind Coordinating Committee, Washington, DC, USA.
- Podolsky, R. (2005) Application of Risk Assessment Tools: Avian Risk of Collision Model. In *Proceedings of the Onshore Wildlife Interactions with Wind Developments: Research Meeting V.*, Lansdowne, VA, 3-4 November 2004, p. 86-87 (Ed. Schwartz, S.S.). RESOLVE, Inc. prepared for the Wildlife Subcommittee of the National Wind Coordinating Committee. Washington, DC, USA.
- Poot, M. J., van Horssen, P. W., Collier, M. P., Lensink, R. & Dirksen, S. (2012) *Effect studies offshore wind Egmond aan Zee: cumulative effects on seabirds. A modelling approach to estimate effects on population levels in seabirds*. Bureau Waardenburg bv, Culemborg, The Netherlands.
- Prinsen, H. A. M., Boere, G. C., Pires, N. & Smallie, J. J. (2011a) *Review of the conflict between migratory birds and electricity power grids in the African-Eurasian region*. CMS Technical Series No. XX, AEW Technical Series No. XX, produced by Bureau Waardenburg for the Convention on Migratory Species Bonn, Germany.
- Prinsen, H. A. M., Smallie, J. J., Boere, G. C. & Pires, N. (2011b) *Guidelines on how to avoid or mitigate impact of electricity power grids on migratory birds in the African- Eurasian region*. CMS Technical Series no. XX, AEW Technical Series no. XX, produced by Bureau Waardenburg for the Convention on Migratory Species, Bonn, Germany.
- Redpath, S. M., Thirgood, S. J. & Clarke, R. (2002) Field vole *Microtus agrestis* abundance and hen harrier *Circus cyaneus* diet and breeding in Scotland. *Ibis*, **144**: 33-38.
- Rees, E. C. (2012) Impacts of wind farms on swans and geese: A Review. *Wildfowl*, **62**: 37-72.
- Rempel, R. S., Hobson, K. A., Holborn, G., Van Wilgenburg, S. L. & Elliott, J. (2005) Bioacoustic monitoring of forest songbirds: interpreter variability and effects of configuration and digital processing methods in the laboratory. *Journal of Field Ornithology*, **76**(1): 1-11.

- Rexstad, E. & Buckland, S. (2012) *Displacement analysis boat surveys Kentish Flats*. Report SOSS-01A, Centre for Research into Ecological and Environmental Modelling, University of St. Andrews on behalf of the Strategic Ornithological Support Services (SOSS) steering group, St. Andrews, UK.
http://www.bto.org/sites/default/files/u28/downloads/Projects/Final_Report_SOSS01A.pdf
 [accessed 28 March 2013].
- Ronconi, R. A., St Clair, C. C., O'Hara, P. D., Burger, A. E., Day, R. H. & Cooper, B. A. (2004) Waterbird deterrence at oil spills and other hazardous sites: potential applications of a radar-activated on-demand deterrence system. *Marine Ornithology*, **32**: 25-33.
- Roy, S. B. & Traiteur, J. J. (2010) Impacts of wind farms on surface air temperatures. *Proceedings of the National Academy of Sciences of the United States of America*, **107**: 17899-17904
- Ruddock, M. & Whitfield, D. P. (2007) *A Review of Disturbance Distances in Selected Species*. A report by Natural Research (Projects) Ltd. on behalf of Scottish Natural Heritage, Scotland, UK.
<http://www.snh.org.uk/pdfs/strategy/renewables/birdsd.pdf> [accessed 30 July 2013].
- Rydell, J., Engström, H., Hedenström, A., Larsen, J. K., Pettersson, J. & Green, M. (2012) *The effect of wind power on birds and bats: A synthesis*. This report is a translation of the previous report in Swedish "Vindkraftens effekter på fåglar och fladdermöss". Vindval report to the Swedish Environmental Protection Agency, Lund/Stockholm, Sweden.
- Schaub, M. (2012) Spatial distribution of wind turbines is crucial for the survival of red kite populations. *Biological Conservation*, **155**: 111-118.
- Schwemmer, P., Mendel, B., Sonntag, N., Dierschke, V. & Garthe, S. (2011) Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. *Ecological Applications*, **21**: 1851-1860.
- SDC (2007) *Turning the Tide: Tidal Power in the UK*. Sustainable Development Commission, London, UK. <http://www.sd-commission.org.uk/publications.php?id=607> [accessed 30 July 2013].
- Shaffer, S. A., Costa, D. P. & Weimerskirch, H. (2003) Foraging effort in relation to the constraints of reproduction in free-ranging albatrosses. *Functional Ecology*, **17**: 66-74.
- Smales, I., Muir, S., Meredith, C. & Baird, R. (2013) A description of the Biosis model to assess risk of bird collisions with wind turbines. *Wildlife Society Bulletin*, **37**: 59-65.
- Smallwood, K. S. (2007) Estimating wind turbine-caused bird mortality. *Journal of Wildlife Management*, **71**: 2781-2791.
- Smallwood, K. S. (2013) Comparing bird and bat fatality-rate estimates among North American wind-energy projects. *Wildlife Society Bulletin*, **37**(1):19-33.
- Smallwood, K. S., Bell, D. A., Snyder, S. A. & DiDonato, J. E. (2010) Novel scavenger removal trials increase estimates of wind turbine-caused avian fatality rates. *Journal of Wildlife Management*, **74**: 1089-1097.
- Smallwood, K. S. & Karas, B. (2009) Avian and bat fatality rates at old-generation and repowered wind turbines in California. *Journal of Wildlife Management*, **73**: 1062-1071.
- Smallwood, K. S. & Neher, L. (2004) *Repowering the APWRA: Forecasting and Minimizing Avian Mortality without Significant Loss of Power Generation*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-005.
- Smallwood, K. S., Ruge, L. & Morrison, M. L. (2009) Influence of behavior on bird mortality in wind energy developments. *Journal of Wildlife Management*, **73**: 1082-1098.
- Smallwood, K. S. & Thelander, C. G. (2004) *Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area*. Final Report by BioResource Consultants to the California Energy Commission, Public Interest Energy Research-Environmental Area, Ojia, CA, USA.

- Smallwood, K. S. & Thelander, C. G. (2008) Bird mortality in the Altamont Pass Wind Resource Area, California. *Journal of Wildlife Management*, **72**(1): 215-223.
- Smallwood, K. S., Thelander, C. G., Morrison, M. L. & Rugge, L. M. (2007) Burrowing owl mortality in the Altamont Pass Wind Resource Area. *Journal of Wildlife Management*, **71**: 1513-1524.
- SNH (2000) *Wind farms and birds: calculating a theoretical collision risk assuming no avoiding action* [the “Band” model]. Scottish Natural Heritage, Inverness, UK. <http://www.snh.gov.uk/docs/C205425.pdf> [accessed 30 July 2013].
- SNH (2005) *Survey methods for use in assessment of the impacts of proposed onshore wind farms on bird communities*. Scottish Natural Heritage, Inverness, UK. http://www.snh.org.uk/pdfs/strategy/renewable/bird_survey.pdf [accessed 30 July 2013].
- SNH (2009a) *Monitoring the impact of onshore wind farms on birds*. Scottish Natural Heritage, Inverness, UK. <http://www.snh.gov.uk/docs/C205416.pdf> [accessed 30 July 2013].
- SNH (2009b) *Siting and Designing windfarms in the landscape*. Version 1. Scottish Natural Heritage, Inverness, UK. <http://www.snh.gov.uk/docs/A337202.pdf> [accessed 02 Aug 2013].
- SNH (2010a) *Avoidance rate information & guidance note: Use of avoidance rates in the SNH wind farm collision risk model*. Scottish Natural Heritage, Edinburgh, UK. <http://www.snh.gov.uk/docs/B721137.pdf> [accessed 08 Aug 2013].
- SNH (2010b) *Survey methods for use in assessing the impacts of onshore windfarms on bird communities*. Revised edition. Scottish Natural Heritage, Inverness, UK. <http://www.snh.gov.uk/docs/C278917.pdf> [accessed 30 July 2013].
- SNH (2013) *Avoidance rates for wintering species of geese in Scotland at onshore wind farms*. Scottish Natural Heritage, Edinburgh, UK. <http://www.snh.gov.uk/docs/A916616.pdf> [accessed 08 Aug 2013].
- Stewart, G. B., Pullin, A. S. & Coles, C. F. (2005) *Systematic Review No. 4: Effects of Wind Turbines on Bird Abundance*. Collaboration for Environmental Evidence, Centre for Evidence-Based Conservation, University of Birmingham, Birmingham, UK.
- Stienen, E. W. M., Courtens, W., Everaert, J. & van de Walle., M. (2008) Sex-biased mortality of common terns in wind farm collisions. *The Condor*, **110**: 154-157.
- Strickland, M. D., Arnett, E. B., Erickson, W. P., Johnson, D. H., Johnson, G. D., Morrison, M. L., Shaffer, J. A. & Warren-Hicks, W. (2011) *Comprehensive Guide to Studying Wind Energy/Wildlife Interactions*. Report prepared for the National Wind Coordinating Collaborative, Washington, D.C., USA. http://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdf [accessed 29 April 2013].
- Strickland, M. D., Erickson, W. P., Johnson, G., Young, D. & Good, R. (2001) *Risk Reduction Avian Studies at the Foote Creek Rim Wind Plant in Wyoming*. p. 107-114. Proceedings of the National Avian-Wind Power Planning Meeting IV, Carmel, CA, USA.
- Strickland, M. D., Young Jr., D. P., Johnson, G. D., Derby, C. E., Erickson, W. P. & Kern, J. W. (1998) *Wildlife monitoring studies for the SeaWest Wind Power development, Carbon County, Wyoming*. pp. 55-63. Proceedings of National Avian-Wind Power Planning Meeting III, San Diego, California, USA.
- Taylor, M. K., Laake, J., Mcloughlin, P. D., Cluff, H. D. & Messier, F. (2006) Demographic parameters and harvest-explicit population viability analysis for polar bears in M’Clintock Channel, Nunavut, Canada. *Journal of Wildlife Management*, **70**: 1667-1673.
- Thaxter, C. B. & Burton, N. H. K. (2009) *High definition imagery for surveying seabirds and marine mammals: a review of recent trials and development of protocols*. COWRIE/BTO Workshop-09, BTO report commissioned by COWRIE Ltd., London, UK.

- Thaxter, C. B., Lascelles, B., Sugar, K., Cook, A. S. C. P., Roos, S., Bolton, M., Langston, R. H. W. & Burton, N. H. K. (2012) Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation*, **156**: 53-61.
- Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., de Siqueira, M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Oerson, T., Phillips, O. L. & Williams, S. E. (2004) Extinction risk from climate change. *Nature*, **427**: 145-148.
- Tucker, V. A. (1996) A mathematical model of bird collisions with wind turbine rotors *Journal of Solar Energy Engineering-Transactions of the Asme*, **118**: 253-262.
- UKCP09 (2009) *The UK Climate Projections*. DEFRA, London, UK. <http://ukclimateprojections.defra.gov.uk/21708> [accessed 30 July 2013].
- Usher, B. (2005) *Conserving European biodiversity in the context of climate change*. Report for the Bern Convention Standing Committee T-PVS (2005) 21, School of Biological and Environmental Sciences, University of Stirling, Stirling, UK. http://www.coe.int/t/dg4/cultureheritage/nature/bern/ClimateChange/Documents/tpvs212005Usher_en.pdf [accessed 30 July 2013].
- Vanermen, N., Stienen, E.W. M., Onkelinx, T., Courtens, W. & Van de walle, M. (2011) Seabirds & offshore wind farms: Power and impact analyses 2010. In: *Offshore wind farms in the Belgian part of the North Sea: selected findings from the baseline and targeted monitoring* (Eds: Degraer, S., Brabant, R. & Rumes, B), Chapter 9, p.93-129. Management Unit of the North Sea Mathematical Models, Royal Belgian Institute of Natural Sciences, Belgium.
- Vanermen, N., Stienen, E. W. M., Onkelinx, T., Courtens, W., Van de walle, M., Verschelde, P. & Verstraete, H. (2012) Seabirds & Offshore Wind Farms: Monitoring Results 2011. In: *Offshore wind farms in the Belgian part of the North Sea: selected findings from the baseline and targeted monitoring* (Eds. Degraer, S., Brabant, R. & Rumes, B), Chapter 7, p.93-129. Management Unit of the North Sea Mathematical Models, Royal Belgian Institute of Natural Sciences, Belgium.
- Walker, D., McGrady, M., McCluskie, A., Madders, D. & McLeod, D. R. A. (2005) Resident Golden Eagle ranging behaviour before and after construction of a windfarm in Argyll. *Scottish Birds*, **25**: 24-40.
- Walls, R., Canning, S., Lye, G., Givens, L., Garrett, C. & Lancaster, J. (2012) *Robin Rigg Offshore Wind Farm, Scotland*. Natural Power Consultants report to EON Climate & Renewables, analysis of MEMP Ecological Data (Operational Year 1), Technical Report 035_R_NPC_EON_4, Falkirk, UK.
- Walls, R., Pendlebury, C., Budgey, R., Brookes, K. & Thompson, P. (2009) *Revised best practice guidance for the use of remote techniques for ornithological monitoring at offshore windfarms*. COWRIE REMTECH-08-08, report commissioned by COWRIE Ltd., London, UK.
- Walsh-Thomas, J. M., Cervone, G., Agouris, P. & Manca, G. (2012) Further evidence of impacts of large-scale wind farms on land surface temperature. *Renewable and Sustainable Energy Reviews*, **16**: 6432-6437.
- Watts, B. D. (2010) *Wind and waterbirds: establishing sustainable mortality limits within the Atlantic Flyway*. Center for Conservation Biology Technical Report Series, CCBTR-05-10. College of William and Mary/Virginia Commonwealth University, Williamsburg, Virginia, USA.
- Weimerskirch, H., Salamolard, M., Sarrazin, F. & Jouventin, P. (1993) Foraging strategy of wandering albatrosses through the breeding season: a study using satellite telemetry. *The Auk*, **110**: 325-342.
- Whitfield, D. P. (2009) *Collision Avoidance of Golden Eagles at Wind Farms under the 'Band' Collision Risk Model*, National Research Ltd., Banchory, UK.
- Whitfield, D. P. & Leckie, F. M. (2012) *Hen Harriers In The Vicinity Of Wind Farms In County Tyrone, Northern Ireland: A Review*. Natural Research Projects Ltd., Banchory, UK.

- Whitfield, D. P. & Madders, M. (2006) *Flight height in the Hen Harrier Circus cyaneus and its incorporation in wind turbine collision risk modelling*. National Research Ltd., Banchory, UK.
- Wiggelinkhuizen, E. J. & den Boon, J. H. (2010) *Monitoring of bird collisions in wind farm under offshore-like conditions using WT-BIRD system*. FINAL report ECN-E—09-033, Energy Research Centre of the Netherlands, Petten, The Netherlands. <http://www.ecn.nl/docs/library/report/2009/e09033.pdf> [accessed 29 April 2013].
- Williams, P., Gibbons, D., Margules, C., Rebelo, A., Humphries, C. & Pressey, R. (1996) A comparison of richness hotspots, rarity hotspots, and complementary areas for conserving diversity of British birds. *Conservation Biology*, **10**: 155-174.
- Winkelman, J.E. (1992) *The impact of the Sep wind park near Oosterbierum (Fr.), the Netherlands, on birds, 1: collision victims* [Dutch with English summary]. RIN-rapport 92/2. DLO-Instituut voor Bos-en Natuuronderzoek, Arnhem, The Netherlands. <http://www.alterra.nl> [accessed 30 July 2013].
- WWT Consulting, MacArthur Green Ltd. & RPS (2012) *Demographic data, population model and outputs* [Gannet Population Viability Analysis]. Report commissioned by The Crown Estate, via its Strategic Ornithological Support Services, Project SOSS-04, The Crown Estate, London, UK. <http://www.bto.org/science/wetland-and-marine/soss/projects> [accessed 06 Sept 2012].
- Young, D. P., Erickson, W. E., Strickland, M. D., Good, R. E. & Sernka, K. J. (2003) *Comparison of Avian Responses to UV-Light-Reflective Paint on Wind Turbines*. National Renewable Energy Laboratory, Golden, CO, USA.

USEFUL WEBSITES, WEBPAGES AND ONLINE REPORTS

The following is a (not comprehensive) list of useful websites, webpages and online reports not directly referenced above.

The original Bern Convention Report document T-PVS/Inf (2003) 12 - *Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental impact assessment criteria and site selection issues* (2003):

<https://wcd.coe.int/com.instranet.InstraServlet?command=com.instranet.CmdBlobGet&InstranetImage=1713295&SecMode=1&DocId=1441704&Usage=2>

- Recommendation No. 109 (2004) of the Standing Committee on minimising adverse effects of wind power generation on wildlife, adopted by the Standing Committee on 3 December 2004, is available at:
[https://wcd.coe.int/ViewDoc.jsp?Ref=Rec\(2004\)109&Language=lanEnglish&Ver=original&Site=DG4-Nature&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FD C864](https://wcd.coe.int/ViewDoc.jsp?Ref=Rec(2004)109&Language=lanEnglish&Ver=original&Site=DG4-Nature&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FD C864)
- All documents related to bird conservation issues produced under the Bern Convention are downloadable through the following link:
http://www.coe.int/t/dg4/cultureheritage/nature/bern/birds/default_en.asp

Bats and Wind Energy Co-operative (BWEC):

http://www.batsandwind.org/index.php?option=com_content&view=article&id=49&Itemid=65

Bern Convention pages on the Emerald Network:

- *Summary* - http://www.coe.int/t/dg4/cultureheritage/nature/EcoNetworks/Default_en.asp
- *Reference Portal* - http://www.coe.int/t/dg4/cultureheritage/nature/EcoNetworks/Default_en.asp

- *Criteria for assessing national lists -*
<https://wcd.coe.int/com.instranet.InstraServlet?command=com.instranet.CmdBlobGet&InstranetImage=1760221&SecMode=1&DocId=1651100&Usage=2>

BirdLife Europe Report – *Meeting Europe’s Renewable Energy Targets in Harmony with Nature* (2011): http://www.rspb.org.uk/Images/Renewable_energy_report_tcm9-297887.pdf

Budapest Declaration – Powerlines and Bird Mortality in Europe International Conference (2011):
<http://www.mme.hu/component/content/article/20-termeszetvedelemfajvedelem/1387-budapest-conference-13-04-2011.html>

Canadian Wildlife Service/Environment Canada – Wind Turbines and Birds: A Guidance Document for Environmental Impact Assessment (2007):
<http://www.batsandwind.org/pdf/Wind%20Turbines%20and%20birds%20A%20guidance%20document%20for%20environmental%20assessment.pdf>

Chartered Institute of Ecology and Environmental Management (UK): <http://www.cieem.net/>

Conference on Wind Energy and Wildlife Impacts (2011): <http://cww2011.nina.no/>

Convention for Biological Diversity – EIA pages: <http://www.cbd.int/impact/>

COWRIE (Huddleston, 2010): produced a range of guidance documentation on marine bird survey methodologies including visual aerial and boat-based surveys (Camphuysen *et al.*, 2004), digital aerial surveys (Thaxter & Burton, 2009; Buckland *et al.*, 2012), remote techniques including radar and thermal imaging (Desholm, 2005; Walls *et al.*, 2009).

Eolien – Biodiversite project website (LPO, France): http://www.eolien-biodiversite.com/contenu/_le-programme--eolien-biodiversite.3

European Commission pages on:

- Environmental Impact Assessment: <http://ec.europa.eu/environment/eia/eia-support.htm>
- Strategic Environmental Assessment: <http://ec.europa.eu/environment/eia/home.htm>
- Birds Directive: http://ec.europa.eu/environment/nature/conservation/wildbirds/index_en.htm
- Habitats Directive Article 6:
http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm
- Wind energy developments and Natura 2000 guidance: Wind energy development in accordance with the EU nature legislation:
http://ec.europa.eu/environment/nature/natura2000/management/docs/Wind_farms.pdf

Good Practice Wind (2010): <http://www.project-gpwind.eu/>

International Association for Impact Assessment: <http://www.iaia.org/>

National Wind Co-ordinating Collaborative (NWCC): <http://www.nationalwind.org/>

- Including their *Comprehensive Guide to Studying Wind Energy/Wildlife Interactions* (June 2011): -
http://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdf

Natural England Wind Energy Guidance: <http://publications.naturalengland.org.uk/category/34022>

Norwegian Institute for Nature Research (NINA) - *Renewable Energy Respecting Nature* (Oct 2012):
<http://www.nina.no/archive/nina/PppBasePdf/rapport/2012/874.pdf>

Ontario Ministry of Natural Resources – *Bird and Bird Habitats: Guidelines for Wind Power Projects* (Dec 2011):
http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@renewable/documents/document/stdprod_071273.pdf

Scottish Natural Heritage (SNH) (2012) *Windfarm impacts on birds guidance*. Scottish Natural Heritage, Inverness, UK: <http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/windfarm-impacts-on-birds-guidance/>

Survey techniques – standard bird survey/census techniques should be applicable to the species concerned, best practice guidance is available see Gilbert *et al.*, 1998; Hardey *et al.*, 2009; Common Birds Census (CBC): <http://www.bto.org/about-birds/birdtrends/2012/methods/common-birds-census>

US Fish and Wildlife Service Wind Energy Guidance (Mar 2012): <http://www.fws.gov/windenergy/>

APPENDICES

Appendix I – Key Legislation and Conventions

Two legal instruments are of particular importance for the conservation of birds and habitats within Europe, Directive 2009/147/EC on the Conservation of Wild Birds and Directive 92/43/EEC (the ‘Birds Directive’) on the Conservation of Natural Habitats and of Wild Flora and Fauna (the ‘Habitats Directive’). They provide the framework for protecting sites – Special Protection Areas (SPA) and Special Areas of Conservation (SAC). Together, these sites are known as Natura 2000. In addition, particular species, identified in annexes to these Directives, receive special protection outwith the Natura 2000 network.

There are two key pieces of legislation in Europe governing environmental assessment, Directive 2001/42/EC on the Assessment of the Effects of Certain Plans and Programmes on the Environment (the ‘SEA Directive’) & Directive 2011/92/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment (the ‘EIA Directive’).

There are several international conventions that apply in signatory countries and some have developed guidance on how to tackle issues relating to wind energy and nature conservation and impact assessment more generally:

- The Convention on the Conservation of Migratory Species of Wild Animals (**CMS**) (including the African Eurasian Waterbird Agreement (**AEWA**));
- The Convention on the Conservation of European Wildlife and Natural Habitats (**Bern Convention**);
- The Convention on Wetlands of International Importance (**Ramsar Convention**); and
- The Convention for the Protection of the Marine Environment of the North East Atlantic (**OSPAR**).

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

Resolution 7.5 on Wind Turbines and Migratory Species was adopted by the 7th meeting of the Conference of Parties (2002). This called upon Parties to the Convention to:

- Identify areas where migratory species are vulnerable to wind turbines and where wind turbines should be evaluated to protect migratory species;
- Apply and strengthen, where major developments of wind turbines are planned, comprehensive SEA assessment procedures to identify appropriate construction sites;
- Evaluate the possible negative ecological impacts of wind turbines on nature, particularly migratory species, prior to decision upon permission for wind turbines;
- Assess cumulative environmental impacts of installed wind turbines on migratory species; and
- Take full account of the precautionary principle in the development of wind turbine plants, and to develop wind energy parks taking account of environmental impact data and monitoring information as it emerges and taking account of exchange of information provided through the spatial planning processes.

The African-Eurasian Waterbird Agreement (AEWA)

The African-Eurasian Waterbird Agreement (AEWA) of the Convention on Migratory Species adopted Resolution 5.16 on ‘Renewable Energy and Migratory Birds’ in 2012. This:

- *Calls upon* Contracting Parties to develop and strengthen national renewable energy planning and development to include monitoring in order to avoid and minimise adverse effects of renewable energy installations (including for biofuels) on waterbirds, and in particular to:

- Carefully evaluate potential sites for the development of new renewable energy installations where there is a likelihood of significant negative impacts on migratory waterbirds, *inter alia* by undertaking strategic environmental assessments and environmental impact assessments (SEA and EIA), developing sensitivity and zoning maps, thereby avoiding existing protected areas, such as Ramsar Sites and Special Protection Areas, or other sites of importance (including Important Bird Areas) where rigorous and complete SEA and EIA show significant negative impacts on migratory waterbirds;
- In addition, where rigorous and complete SEA and EIA show significant negative impacts on migratory waterbirds, avoid sites located within the main migration corridors of migratory waterbirds which have been shown to experience high bird densities, such as wetlands, coastlines, ridges and other topographic features, also taking into consideration possible indirect effects such as disturbance, displacement, loss or deterioration of habitats;
- Strengthen, if necessary, national level cross-sectoral land-use planning and ensure that the vital needs of migratory waterbird species are mainstreamed within energy policy;
- Ensure that water usage in renewable energy processes does not affect critical waterbird habitats and is economised where this might be the case, and that possible negative impacts of construction of infrastructure related to renewable energy installations, such as the building of roads and power lines, are kept at the minimum level;
- Follow existing international environmental guidelines, recommendations and criteria for the project-level environmental impact assessment development and utilisation of renewable energy sources;
- Use AEWA Guideline No. 11 on how to avoid, minimise or mitigate the impacts of infrastructural developments and related disturbance affecting waterbirds and widely disseminate this to interested Parties;
- Encourage post-development monitoring of renewable energy installations and associated infrastructure in order to identify possible effects on biodiversity and ensure that lessons learned from post-development monitoring feed into the process for planning future developments;
- Encourage the mitigation of adverse effects of existing renewable energy installations and associated infrastructure where such effects have been identified;
- Share information from post-construction monitoring and mitigation measures in renewable energy installations on observed effects on migratory waterbirds and their habitats, so Parties can benefit from lessons learned and so that cumulative impacts of renewable energy installations can be assessed at the flyway level;
- Consider, where damage cannot be avoided or mitigated, the possibility of compensation for damages to biodiversity resulting from the development of renewable energy installations in accordance with national legislation as well as Ramsar Resolution VII.24 *Compensation for lost wetland habitats and other functions* (1999) and Ramsar Resolution VIII.20 *General guidance for interpreting "urgent national interest" under Article 2.5 of the Convention and considering compensation under Article 4* (2002);
- 2. *Further calls upon* Contracting Parties to undertake specific measures to reduce the potential negative impact of terrestrial as well as marine wind farms on waterbirds, *inter alia* by:
 - 2.1 Encouraging wind farm operators to operate wind farms in ways that minimise bird mortality, for example by introducing short-term shutdowns during peak migration and minimising lighting in wind farms;
 - 2.2 Further encouraging the dismantling of wind turbines in existing installations, should waterbird mortality have an effect on the population status of a species and other mitigation measures have proved insufficient;

- 2.3 Focusing research efforts on alleviating the negative effects on waterbirds from wind farms, such as the mapping of the main migration corridors and migration crossings for waterbirds also allowing the optimising of wind farm layouts;
- *Further calls upon* Contracting Parties to pay particular attention and undertake specific measures to assess, identify and reduce potential negative impacts of biofuel production on waterbirds building on the approaches established in Resolution X.25 of the Ramsar Convention on wetlands and biofuels;
- *Urges* Parties and *invites* non-Contracting Parties, inter-governmental organisations and other relevant institutions, as appropriate, to include the measures contained in this Resolution in their National Biodiversity Strategies and Action Plans and relevant legislation, if applicable, in order to ensure that the impact of renewable energy developments on waterbird populations is minimised, and *calls on* Parties to report progress in implementing this Resolution to each Meeting of the Parties as part of their National Reports; and
- *Requests* the Technical Committee, in liaison with relevant industry bodies and other interested parties, to identify key knowledge gaps and/or deficiencies in guidance related to the impact of renewable energy production and migratory waterbirds, and make proposals as to how these might most effectively be filled.

http://www.unep-aewa.org/meetings/en/mop/mop5_docs/final_res_pdf/res_5_16_renewables.pdf

Bern Convention

The Secretariat of Council of Europe, on behalf of the Standing Committee to the Bern Convention, commissioned BirdLife International to produce a report on Birds and wind farms (Langston & Pullan 2003), which provided the basis for [Recommendation No. 109 \(2004\) on minimising adverse effects of wind power generation on wildlife](#). This recommends that Contracting Parties to the Convention:

- Take appropriate measures to minimise potential adverse effects of wind turbines on wildlife; and
- Support and advance by involving also the wind energy sector adequate monitoring and surveillance to improve understanding on the impact of wind farms.

[https://wcd.coe.int/ViewDoc.jsp?Ref=Rec\(2004\)109&Language=lanEnglish&Ver=original&Site=DG4-Nature&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FDC864](https://wcd.coe.int/ViewDoc.jsp?Ref=Rec(2004)109&Language=lanEnglish&Ver=original&Site=DG4-Nature&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FDC864)

An ad hoc working group was further established, by the Council of Europe with the European Commission, to develop best practice guidance. This resulted in the EC Guidance Document on Wind Energy Developments and Natura 2000 (European Commission, 2010).

Ramsar Convention

Resolution XI.10 ‘Wetlands and Energy Issues’ includes many statements applicable to wind energy development, and contains guidance statements on such things as the Spatial Planning, SEA and EIA of energy developments.

<http://www.ramsar.org/pdf/cop11/res/cop11-res10-e.pdf>

This is linked to previous Resolution VII.16 on ‘the Ramsar Convention and Impact Assessment: Strategic, Environmental and Social’.

http://www.ramsar.org/pdf/res/key_res_vii.16e.pdf

OSPAR

OSPAR has created guidance on the licensing, environmental assessment, monitoring and decommissioning of offshore windfarms. The latest iteration of this guidance is 'OSPAR Guidance on Environmental Considerations for Offshore Windfarm Development' (2008/3):

http://www.ospar.org/v_measures/browse.asp