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Guidance document on wind energy developments and EU nature legislation

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Guidance document on wind energy developments and EU Nature Legislation

This guidance document is not legally binding; its sole purpose is to provide information on certain aspects of the relevant EU legislation. It is thus intended to assist citizens, businesses and national authorities in the application of the Birds and Habitats Directives. It does not prejudge any future position of the Commission on the matter. Only the Court of Justice of the European Union is competent to authoritatively interpret Union law. This guidance document does not replace, add to or amend the provisions of the Birds and Habitats Directives; furthermore it should not be considered in isolation but used in conjunction with this legislation.

European Commission, 2020

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ABOUT THIS DOCUMENT

Background to this document

This document provides an update of the 2011 Commission guidance on wind energy and Natura 2000, as planned in the action plan for nature, people and the economy[1]. An update of the guidance was considered necessary as EU policy and legislation on renewable energy and wind energy technology (especially at sea) has developed greatly since the guidance was first issued. In step with these developments, knowledge on the impacts of wind energy on biodiversity as well as good practice for addressing these impacts has also expanded significantly. In view of further drastic expansion of wind energy in the context of tackling climate change on the one hand and growing pressures on biodiversity on the other hand, guidance based on most recent insights and good practices on reconciling the respective policy goals and targets is essential.

The Renewable Energy Directive[2] adopted in 2009 sets a binding target of 20% final energy consumption to come from renewable sources by 2020. In 2018, the European Parliament and the Council adopted the revised Renewable Energy Directive[3], setting a binding EU-level renewable energy target of at least 32% by 2030, with a clause to revise this figure upwards by 2023. Wind energy accounts for the highest share of renewable energy production in the European Union (EU) and is expected to remain so over the coming decades. In 2018, with an installed capacity of 170 GW onshore and 19 GW offshore, wind energy accounted for 18.4% of the EU's total electricity generation capacity[4]. With renewable power generation potentially reaching 50% of total electricity generation in the EU by 2030, wind energy (both onshore and offshore) could account for 21% of total power generation[5].

In December 2019, the European Commission presented a communication on the European Green Deal[6]. It resets the Commission's commitment to tackling climate and environment-related challenges that is this generation's defining task and is an integral part of the Commission's strategy to implement the United Nations' 2030 sustainable development goals (SDGs). It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, sustainable, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. The Green Deal has already set out a clear vision on how to achieve climate neutrality by 2050 and how to further decarbonise the energy system in order to reach climate objectives in 2030 and 2050. It highlights the essential role of renewable energy sources, in particular of offshore wind energy production, in achieving these objectives.

The European Green Deal attaches also particular importance to biodiversity, which is under increasing pressure. The European Commission has also recently adopted a communication on the EU Biodiversity Strategy for 2030[7] which aims to put Europe's biodiversity on a path to recovery by 2030 with benefits for people, the climate and the planet. This strategy contains commitments and actions to be delivered by 2030, including the establishment of a larger EU-wide network of protected areas on land and at sea, building upon existing Natura 2000 areas, with strict protection for areas of very high biodiversity and climate value, an EU Nature Restoration Plan, a set of measures to enable the necessary transformative change, as well as measures to tackle the global biodiversity challenge. The report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on a Global assessment of biodiversity and ecosystem services[8] also provides an alarming picture of the state of biodiversity and the different pressures on it.

Climate change is generally acknowledged to be a key driver for biodiversity loss. Rising global temperatures cause ecosystem degradation on land and in the sea, with the consequent loss of biodiversity. Wind energy helps conserve biodiversity by saving greenhouse gas emissions, returning significantly more energy back to society than it consumes over its lifecycle. It consumes no water for power generation and does not cause air,

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[1] https://ec.europa.eu/environment/nature/legislation/fitness_check/action_plan/communication_en.pdf
[2] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
[4] Wind energy in Europe in 2018. Trends and statistics' (WindEurope, 2019)
[5] Renewable Energy Prospects for the European Union, International Renewable Energy Agency, 2018
[6] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380
[8] https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services

soil or water pollution during operation. However, poorly sited or poorly designed wind farms can pose a threat to vulnerable species and habitats, including those protected under the Birds and Habitats Directives.

Purpose and nature of this document

The purpose of this document is to provide guidance on how best to ensure that wind energy developments are compatible with the Birds and Habitats Directives.

The scope of this document covers:

- the site protection provisions under Article 6 of the Habitats Directive; as a consequence, the guidance addresses all habitats and species which qualify for designation of Natura 2000 sites, i.e.
- habitats of Community interest listed in Annex I to the Habitats Directive;
- species of Community interest listed in Annex II;
- wild birds listed in Annex I to the Birds Directive;
- regularly occurring migratory wild bird species not listed in Annex I to the Birds Directive;
- the species protection provisions under Articles 12 and 13 of the Habitats Directive and the corresponding provisions of Article 5 of the Birds Directive. These apply both to the strictly protected species under Annex IV to the Habitats Directive and to all wild bird species covered by the Birds Directive.

The focus of this document is on wind energy developments regarding the pre-construction, construction, operation and decommissioning or repowering of electricity-generating infrastructure. Associated transmission infrastructure is covered by other European Commission guidance[9].

This sector-specific guidance is part of the broader context of guidance published by the European Commission to facilitate implementation of the Habitats and Birds Directives. The document does not replace the Commission's existing general interpretative and methodological guidance documents on the provisions of Article 6 of the Habitats Directive[10]. Instead, it seeks to clarify specific aspects of these provisions and place them in the context of wind farm development in particular. This guide is therefore best read in conjunction with the two Directives and relevant Commission guidance[11]. Furthermore, this guide draws on the wider principles underpinning EU policy on the environment and wind energy developments (e.g. the principle of 'low-ecological-risk' deployment of renewable energy in Article 15(7) of the revised Renewable Energy Directive). The aim is to provide guidance on the framework for permitting and planning under Articles 15-17 of the revised Renewable Energy Directive.

This document refers to many examples of good practice in case studies (see Appendix A for an overview). They aim to offer real-world examples of effective and smart approaches taken to address impacts when assessing and authorising proposed developments. Because of the very site-specific nature of interactions between wind energy developments and EU-protected habitats and species, these good practices are not intended to be prescriptive but are instead intended to provide a framework or inspiration for developing solutions on a case-by-case basis.

This document is not a piece of legislation; it does not make new rules but provides guidance on how to apply existing rules. Only the Court of Justice of the European Union is competent to authoritatively interpret EU law.

The guidance is designed primarily for use by developers, consultants and competent authorities. It will also be of interest to non-governmental organisations and other stakeholders working in the wind energy sector. The document has been drawn up in consultation with Member State authorities, Non-Governmental Organisations (NGOs) and stakeholders in the wind energy sector, who have provided valuable feedback on the various drafts.

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[9] 'Energy transmission infrastructure and EU Nature legislation' (European Commission, 2018b).
[10] https://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm
[11] In particular, guidance on Article 6 of the Habitats Directive, methodological guidance on Article 6(3)&(4) (available at https://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm), and guidance on species protection (available at https://ec.europa.eu/environment/nature/conservation/species/guidance/index_en.htm).

This document has been prepared with the assistance of Arcadis Belgium nv/sa and NIRAS Consulting Ltd.

Structure of this document

The document contains nine chapters:

- Chapter 1: An overview of the EU policy context with regards to renewable energy, including an overview of the current state of the art of wind energy in the EU and expected trends.
- Chapter 2: An overview of the legal provisions of the Birds and Habitats Directives relevant to wind energy developments, including a particular focus on the permitting procedure under Article 6 of the Habitats Directive for any plans or projects likely to have a significant effect on Natura 2000 sites and on the requirements for EU-protected habitats and species across the wider landscape.
- Chapter 3: General guidance for wind energy developers, operators and planning and permitting authorities on key issues and related good practice. Key issues include the determination of significance of the likely effects, of scoping, setting a baseline of information, dealing with uncertainty, cumulative effects and stakeholder consultation.
- Chapter 4: Discusses the importance of strategic planning and describes support methods such as Wildlife Sensitivity Mapping and the multiple use of sites.
- Chapter 5: Relevant to SDG 15 (‘Life on land’), provides in-depth descriptions of typical impact groups of onshore wind energy developments and how to assess significance of the likely effects related to key receptor groups such as birds, bats and land habitats. Provides an overview of good practice approaches and case studies related to implementation of measures to avoid or reduce significant effects.
- Chapters 6: Relevant to SDG 14 (‘Life below water’), provides in-depth descriptions of typical impact groups of offshore wind energy developments and how to assess significance related to key receptor groups such as seabirds, marine mammals and marine habitats. Provides an overview of good practice approaches and case studies related to implementation of measures to avoid or reduce significant effects.
- Chapter 7: Good practice in monitoring and adaptive management.
- Chapter 8: References
- Chapter 9: Appendices

1 WIND ENERGY IN EUROPE

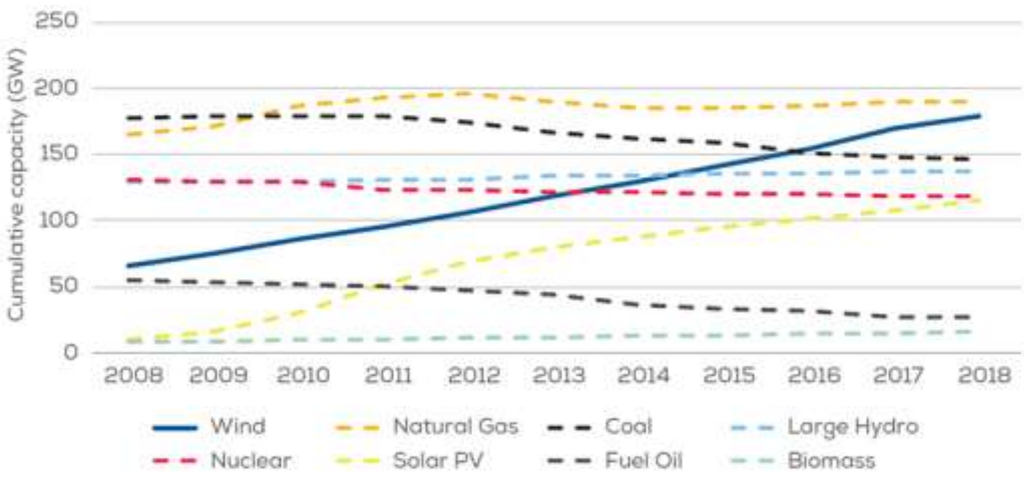
1.1 Introduction

The European Union (EU) has set ambitious targets to decarbonise the economies of Member States by taking a range of actions, including the continued development of renewable energy sources (RES). The Renewable Energy Directive 2009/28/EC[12] establishes an overall policy for the production and promotion of energy from renewable sources. It requires the EU to achieve 20% of energy production from renewables by 2020. With the adoption of the Clean Energy for All Europeans package[13] in 2018 and 2019, the European Union has committed to achieving a share of at least 32% of gross EU final energy consumption from renewables by 2030, including provisions for a possible upward revision. For 2020, EU Member States have committed to specific national renewable energy targets, adopted in their national renewable energy action plans, and supported by a number of related policies and legal instruments. Eurostat data indicate that the EU as a whole is on track to achieve the 2020 target of 20% with a share of renewables varying widely by individual Member State, from over 30% in Finland, Sweden and Latvia, to under 5% in Malta, Luxemburg and the Netherlands[14].

Although considerable progress has been made in developing renewable energy throughout Europe and land-based renewable energy production is relatively well established, a growing number of marine-based energy technologies are experiencing significant growth and are becoming the focus of new policy and legal frameworks. To ensure their sustainable development in Europe, the EU adopted the Maritime Spatial Planning Directive 2014/89/EU[15] with the aim of creating a common framework to reduce conflict between sectors, to create synergies, encourage investment and cross-border cooperation, and preserve the environment. The aims of the Directive are in line with the protection measures set out in the Marine Strategy Framework Directive (MSFD) 2008/56/EC[16] and the Water Framework Directive 2000/60/EC[17].

In 2018, the EU had an installed capacity to produce 160 GW onshore and 19 GW offshore wind energy. This accounted for 14% of the EU's electricity demand and continues to be the second largest form of power generation capacity (Box 1-1).

Box 1-1: Total power generation capacity in the European Union 2008-2018



Source: WindEurope, 2019[18]

12 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028
13 https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en
14 https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics
15 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0089
16 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0056
17 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060
18 https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2018.pdf

1.2 The EU policy framework for promoting renewable energy sources

The EU's renewable energy policy goes back to 1997 with the adoption of the Commission's White Paper entitled: 'Energy for the future: renewable sources of energy'[19]. It recommended doubling the share of renewable energy in gross energy consumption to 12% by 2010 and laid the ground for the adoption of Directive 2001/77/EC on the promotion of electricity from renewable energy sources[20]. The EU then adopted Directive 2003/87/EC[21], which created the EU's greenhouse gas emission trading scheme and aimed to promote decarbonisation and indirectly promote renewable energy sources.

In December 2008, EU Heads of State committed to setting a target for 2020, as part of a Climate and Energy Package'. As part of this, Member States agreed to cut greenhouse gas emissions by at least 20% by 2020 (compared to 1990 levels) and to increase the use of renewable energy sources to 20% of Europe's gross final energy consumption by 2020.

To implement this commitment on renewable energy, the EU adopted Directive 2009/28/EC[22] on the promotion of the use of energy from renewable sources (commonly known as the Renewable Energy Directive (RED)). The RED sets mandatory national targets for each Member State to ensure that overall the EU meets its target of 20% energy from renewable energy sources. Under the Directive, each Member State is required to draw up a clear action plan to demonstrate how they intend to achieve their renewable energy targets. The national renewable action plans adopted by Member States[23] set out the level of ambition across the power, heat and transport sectors, the planned mix of technologies and the policy measures needed to meet the targets.

Building on the level of ambition in 2020 and on the European Commission's proposal as part of a Clean Energy Package, in 2018 the EU established the framework for the 2030 climate and energy strategy[24]. The key EU-level targets for 2030 include:

- at least a 40% reduction in greenhouse gas emissions (based on 1990 levels);
- at least a 32% share of renewable energy consumption, with a clause providing for an upward revision by 2023, binding at EU-level, and
- a headline target to improve energy efficiency at EU-level to at least 32.5%, up from the target of 20% by 2020.

The 2030 renewable energy commitments will be delivered through the revised Directive on the promotion of the use of energy from renewable sources, which was adopted in December 2018 (EU) 2018/2001 (RED II)[25]. Member States are required to collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32%, by providing contributions to the EU-level target. The individual Member States contributions to the EU-level target are set out in integrated national energy and climate plans which include the policy approach and proposed technology mix per Member State in the period up to 2030. Box 1-2 illustrates a forecast of EU total power capacity up to 2050 for the various scenarios under the European Commission's 2050 long-term strategy[26] for reducing its greenhouse gas emissions. It shows that, irrespective of the scenarios chosen, wind and solar are the only sources that will see an increase in capacity, while the remaining sources will either stabilise or see reduced capacity. This long-term strategy predicts that close to 85% of electricity in the EU will be generated from renewable resources by 2050 in decarbonisation scenarios (73% in the baseline, with wind alone representing up to 26% in 2030 and up to 56% in 2050 (European Commission, 2018b)). Onshore wind would represent close to three fourths of total wind capacity in 2030 and two thirds in 2050. Some stakeholders suggest that up to 32% of

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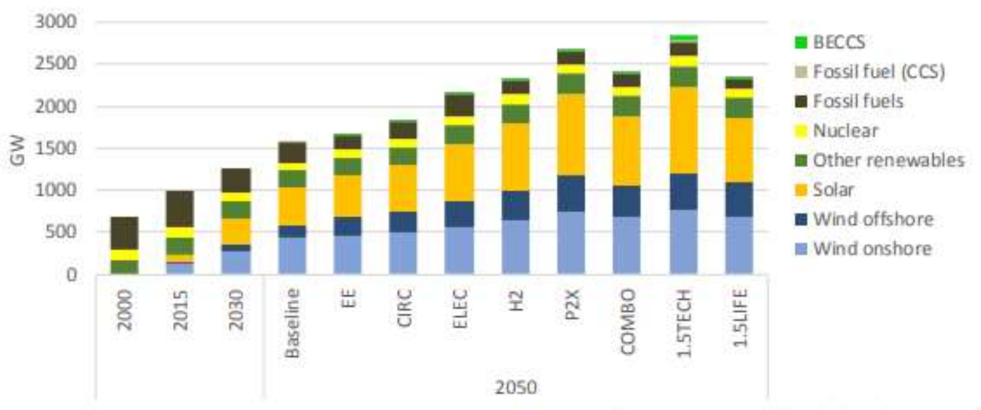
19 https://europa.eu/documents/comm/white_papers/pdf/com97_599_en.pdf
20 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32001L0077
21 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003L0087
22 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028
23 https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020
24 https://ec.europa.eu/clima/policies/strategies/2030_en
25 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
26 https://ec.europa.eu/clima/policies/strategies/2050_en

electricity production from solar PV and wind could be sourced from households, collectives, small and medium-size enterprises and public entities by 2050[27].

To meet the requirements for a climate-neutral energy sector in 2050, the rate of installations in the wind sector will need to increase significantly. According to the Commission's long term strategy, for wind, the capacity will need to increase from the 2018 level of 180 GW to 351 GW in 2030, corresponding to a doubling of capacity. It is anticipated that 263 GW would be installed onshore and 88 GW offshore[28], which is almost five times the 2018 capacity. Depending on the scenario for 2050, wind capacity would increase to between 700 GW under the 'energy efficiency (EE) scenario and to 1200 GW under the 'Power 2X (P2X)' scenario. Translating this into the required space for these developments gives impressive results. Under the maximum scenario (1,5TECH) which assumes a total capacity up to 450 GW offshore (one third), WindEurope expects 85% of the capacity by 2050 to be installed in the northern seas (the Atlantic off France, Ireland and the UK, the North Sea, the Irish Sea and the Baltic Sea) based on the good wind resources, proximity to demand and supply chain efficiencies. This is equivalent to around 380 GW out of the 450 GW. The remaining 70 GW would be located in southern European waters. The total area of the northern seas needed for 380 GW of offshore wind would be 76,000 km2 (assuming 5 MW/km2), an area just under the size of the island of Ireland. This is 2.8% of the total area of the northern seas, without considering exclusion zones. The exact location will depend on the size and available space of the exclusive economic zones (EEZ) of the different Members States and on differences in LCOE[29] , based on sea depth and wind resource. In addition, the final allocation of wind farms will also depend on where energy demand is located. It can be expected that some countries will easily find the space to allocate their capacity, while others will have to either start investing in multiple-use developments or move to more expensive investments (higher LCOE areas).

It is clear that to achieve the targets for wind energy deployment in the most efficient way, both in terms of cost and use of space, multi-use developments and international collaboration will be key. In addition, a step change in permitting processes is required and this needs thorough preparation. As an example, rolling out the required energy grid infrastructure faces similar challenges. More coordinated action by the wind energy sector and grid developers might be very useful, also in view of dealing with cumulative impacts (see Chapter 3.4).

Box 1-2 Projected EU total power capacity scenarios



[27] CE Delft (2016). The potential of energy citizens in the European Union. http://www.foeeurope.org/sites/default/files/renewable_energy/2016/ce-delft-the-potential-of-energy-citizens-eu.pdf

[28] In-depth analysis in support of the Commission Communication COM(2018)773. https://ec.europa.eu/knowledge4policy/publication/depth-analysis-support-com2018-773-clean-planet-all-european-strategic-long-term-vision_en

[29] The concept of levelised cost of electricity (LCOE) is used to compare the cost of energy from different sources. The wide range of electrical power technologies available, both renewable and non-renewable, is quite varied in their physical principles and operation - a solar PV system is drastically different from a biomass power plant. However, the LCOE provides a common basis for comparison: LCOE = Total cost of ownership (€) / System production over its lifetime (kWh). Anything that increases production or reduces cost lowers the LCOE, while anything that decreases production or raises the cost increases the LCOE.

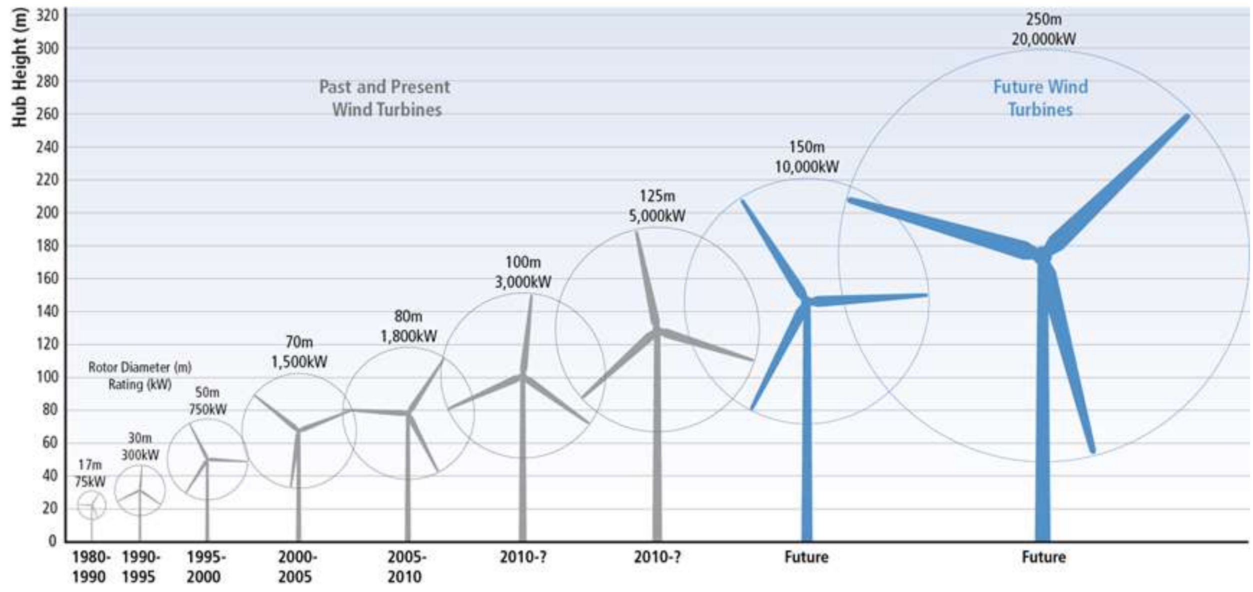
Source: Eurostat (2000, 2015), PRIMES from ‘In-depth analysis in support of the Commission communication COM(2018) 773’[30]

1.3 Trends in wind energy developments

Both onshore and offshore wind energy development sectors are dominated by horizontal-axis wind turbines (HAWTs) with a three-blade configuration. Although other configurations and designs exist, such as vertical-axis wind turbines (VAWTs) and bladeless turbines, they are not expected to contribute significantly to the expected expansion of wind energy capacity in the EU (Communication WindEurope, 2019). The preference for three-bladed HAWTs is due to a number of advantages including aerodynamic efficiency (Gardner *et al.*, 2004).

Developments in the design of onshore and offshore wind energy turbines have yielded an increase in generating capacity together with increasing rotor diameter and hub height (Box 1-3). Offshore turbine models in production (or on order) are in the order of 9.5 MW (9500 kW) with rotor diameters in the order of 164-167 m (Wind Power Monthly, 2018). Larger 10 and 12 MW turbines are under development with rotor diameters in excess of 190 m (Grimwood, 2019). The largest installed onshore turbines in Europe are up to 8 MW (8,000 kW) with rotor diameters of up to 164 m. Increases in rotor diameter and hub height have enabled new wind farms to harness the power of higher and more consistent wind speeds. For onshore wind energy farms, this has allowed turbines to be sited in forest areas where the tree canopy has less of an influence on wind speed and turbulence with increasing turbine height above the ground.

Box 1-3 Design trends: turbine rotor diameter

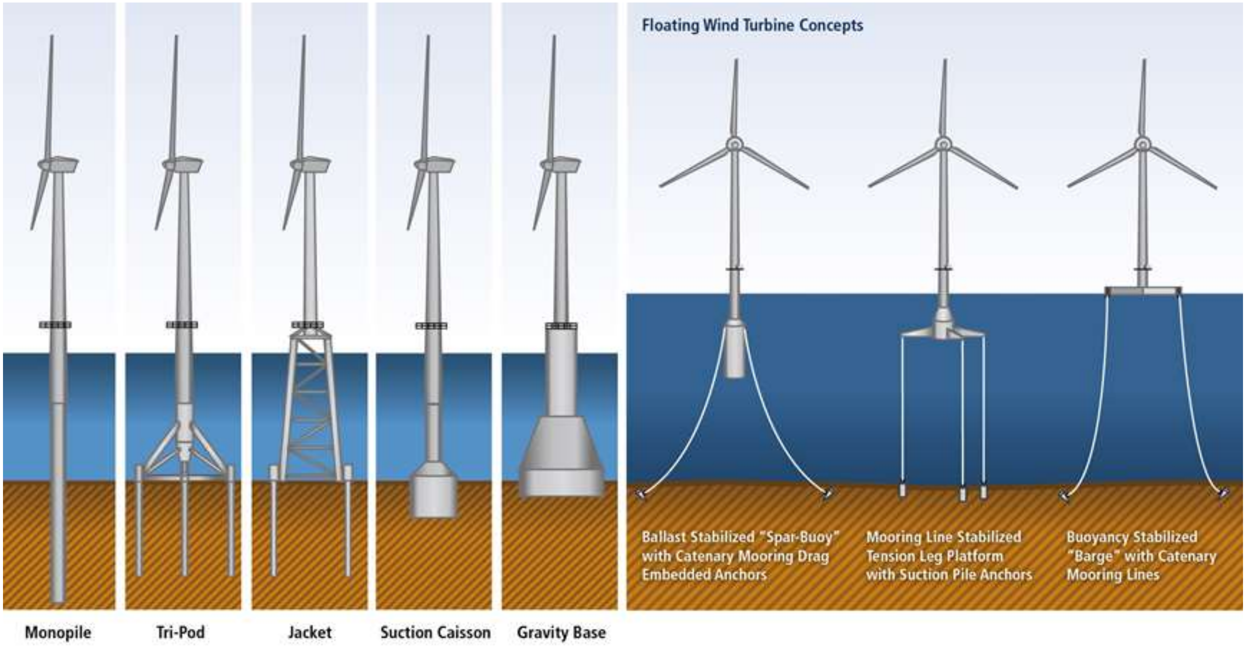


Source: Intergovernmental Panel on Climate Change (IPCC), 2011.

Similarly, developments in foundation design have enabled offshore wind energy farms to be sited in deeper waters where there are higher and more consistent wind speeds (Box 1-4). The emergence of floating turbine technology, with associated installation advantages over traditional fixed-foundation turbine types (WindEurope, 2018) will likely facilitate the shift away from siting turbines in deeper marine waters. In 2019, floating offshore wind energy development generated electricity at three locations in Europe: two in Scotland (Hywind and Kincardine) and one in France (Floatgen Demonstrator).

[30] https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

Box 1-4 Offshore wind turbine foundation types



Source: Intergovernmental Panel on Climate Change (IPCC), 2011.

Commercial-scale wind energy developments deliver 100% of the energy they generate to the national electricity transmission network. Conversely, small (<100 kW) to medium-scale (100-500 kW) turbines produce electricity for on-site use (households, farms, large businesses and small communities) with surplus electricity fed into the national electricity transmission network (RenewableUK, 2014). Unlike commercial-scale wind energy developments, which consist of multiple turbines (a 'wind farm'), small and medium-scale turbines are typically installed as single units. Although the generating capacity of small to medium-scale turbines may be much lower than commercial-scale wind farms, the number of units installed in the EU is very high. It is estimated that in 2015 there were at least 61 437[31] small-capacity turbines in the EU (Pitteloud & Gsänger, 2017).

Small and medium-scale turbines also have the advantage of being able to be incorporated into urban and peri-urban locations. Research into developing and validating innovative solutions to improve their competitiveness, enabling and facilitating the integration and deployment is likely to continue[32]. As technological, economic and social solutions improve, the numbers of both HAWTs and VAWTs in urban and peri-urban areas can be expected to rise. However, not much research has been carried out into the impact of small-scale turbines on birds and bats. There are indications that both bird and bat mortality is caused by collision at relatively low levels, in comparison to other causes of anthropogenic mortality (Minderman *et al.*, 2014).

Lastly, another important trend in wind energy is multiple use of sites. Co-locating wind energy developments with other renewable energy sources, other economic activities or even with ecosystem restoration or nature conservation activities will be key to the efficient use of available space (see Chapter 1.2). Chapter 0 includes a specific section on the multiple use of wind energy development sites.

[31] Cumulative number of installed units in United Kingdom, Germany, Spain, Poland, Sweden, Italy, Ireland, Denmark, Austria and Finland.
[32] See for example 'Wind Energy Integration in the Urban Environment (WINEUR)' (European Commission, 2007) and 'European SWIP project' (CIRCE, 2016).

2 THE EU'S POLICY FRAMEWORK AND LEGISLATION FOR NATURE AND BIODIVERSITY

2.1 The EU biodiversity policy framework

In response to the global Strategic Plan for Biodiversity 2011-2020[33], agreed at the tenth Conference of the Parties to the Convention on Biological Diversity (CBD COP 10), held in Nagoya, Japan, the Commission drafted, in cooperation with Member States, an EU Biodiversity Strategy to 2020[34]. This included a series of targets and a set of feasible and cost-effective measures and actions needed to achieve them.

In May 2020 the European Commission adopted the EU Biodiversity Strategy to 2030[35] which tackles the key drivers of biodiversity loss, such as unsustainable use of land and sea, overexploitation of natural resources, pollution and invasive alien species. The strategy is a central element of the EU's recovery plan[36] aiming to help repair the economic and social damage brought by the coronavirus pandemic, kick-start European recovery, and protect and create jobs. It also aims to make biodiversity considerations an integral part of EU's overall economic growth strategy and stresses the need of having more sustainable sourced renewable energy to fight both climate change and biodiversity loss.

The 2019 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report[37] also once again highlighted the urgent need for ecosystem conservation and restoration. The report states that the rate of global change in nature over the past 50 years is unprecedented in human history and it identifies the key drivers of biodiversity loss. Climate change is ranked as the third main direct driver of biodiversity loss, illustrating the link between renewable energy development and nature conservation. The European Green Deal[38] presented by the Commission provides a framework for further developing EU policy on climate change and biodiversity.

Appendix B sets out a number of other international initiatives on nature conservation that could be relevant to wind energy developments.

2.2 The Birds and Habitats Directives

2.2.1 Introduction

The Birds and Habitats Directives are the cornerstones of the EU's nature and biodiversity policy. They enable all EU Member States to work together, under a common legislative framework, to conserve Europe's most endangered, vulnerable and valuable species and habitats throughout their natural range within the EU, irrespective of political or administrative boundaries. They apply equally to European land and marine territory in the Member States.

The overall objective of the two Directives is to ensure that the species and habitat types they protect are maintained or restored at a favourable conservation status throughout their natural range within the EU. To achieve this objective, the Directives set out two main types of measures:

- designating and conserving core sites for the protection of habitat types and habitats of species listed respectively in Annex I and II to the Habitats Directive and habitats of bird species listed in Annex I to the Birds Directive and of migratory birds. These sites make up the EU-wide Natura 2000 network, which currently includes over 27000 sites, both on land and at sea;

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[33] https://www.cbd.int/sp/
[34] https://ec.europa.eu/environment/nature/info/pubs/docs/brochures/2020%20Biod%20brochure%20final%20lowres.pdf
[35] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380
[36] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590732521013&uri=COM:2020:456:FIN

[37] https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services
[38] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

- creating a strict protection regime for all European bird species and for species listed in Annex IV to the Habitats Directive. These measures apply across the entire natural range of the species within the EU, i.e. both within and outside protected sites.

2.2.2 The protection and management of Natura 2000 sites

The protection and management of Natura 2000 sites is governed by Article 6 of the Habitats Directive, which allows for two types of measures. The first type (Article 6(1) and 6(2)) centres on the conservation and management of all Natura 2000 sites at all times. The second type (Article 6(3) and 6(4)) lays down an assessment and permitting procedure for plans or projects likely to have significant negative effects on Natura 2000 sites.

Article 6(1) and 6(2) of the Habitats Directive requires Member States to:

- take positive conservation measures that correspond to the ecological requirements of habitat types and species present on the sites (Article 6(1));
- take measures to avoid any deterioration of the habitat types or any significant disturbance of the species for which the sites have been designated (Article 6(2)).

To meet the first requirement, Member States must set clear conservation objectives for each Natura 2000 site based on the conservation status and ecological requirements of the habitat types and species of Community interest present. Site-specific conservation objectives define the desired condition of species and habitat types in a site so that the site can contribute to the overall goal of favourable conservation status of these species and habitat types at national, biogeographical or European level. It is particularly important for wind energy developers, planners and authorities to be aware of the conservation objectives for a Natura 2000 site since the potential negative effects of the plan or project will need to be assessed against these conservation objectives.

The Habitats Directive encourages nature authorities to draw up Natura 2000 management plans in close cooperation with local stakeholders. Although not obligatory, these plans can be a very useful source of information on the species and habitat types for which the site has been designated, the site's conservation objectives and, where appropriate, the relationship with other land uses in the area. They also outline the practical conservation measures needed to achieve the site's conservation objectives.

2.2.3 Step-by-step approach for wind farm developments potentially affecting Natura 2000 sites

The information in this chapter is mainly based on:

- **European Commission Guidance 'Managing Natura 2000 sites. The provisions of Article 6 of the Habitats Directive 92/43/EEC'**
- **European Commission Guidance 'Assessment of plans and projects in relation with Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC'**

These guidance documents[39] provide useful clarifications for the interpretation and application of legislation.

The Habitats Directive does not, a priori, exclude wind farm developments in or adjacent to Natura 2000 sites. These need to be assessed on a case-by-case basis. Article 6(3) and (4) (see Box 2-1) sets out a step-by-step assessment and permitting procedure to follow when considering plans or projects that could affect one or more Natura 2000 sites. This procedure is applicable not only to plans or projects within a Natura 2000 site, but also to plans located outside but with a significant potential effect within a site. During the permitting procedure of a plan or project, the competent national authorities must ensure that the assessment of

[39] Available at https://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm

significant effects arising from wind energy plans or projects has been properly carried out. There are three main stages:

- **<u>Stage one</u>: screening**. The first part of the procedure consists of a pre-assessment ('screening') to ascertain whether, firstly, the plan or project is directly connected with or necessary to the management of the Natura 2000 site, and secondly, if it is not, whether it is likely (in the sense of not being excluded) to have a significant effect on the site.
- **<u>Stage two</u>: appropriate assessment**. The second part of the procedure is to make an appropriate assessment of the implications for the site in view of the site's conservation objectives. This assessment must state whether it can be ascertained that the project or plan will not affect the integrity of the Natura 2000 site, either alone or in combination with other projects or plans, taking into account possible mitigation measures.
- **<u>Stage three</u>: derogation from Article 6(3) under certain conditions**. The third stage of the procedure governed by Article 6(4) comes into play if, despite a negative assessment, it is proposed not to reject a plan or project but to assess it further. In this case, Article 6(4) allows for derogations from Article 6(3) under certain conditions, which comprise the demonstrated lack of alternative solutions, and the existence of imperative reasons of overriding public interest to carry out the project. This requires adopting adequate compensatory measures to ensure the overall coherence of the Natura 2000 network.

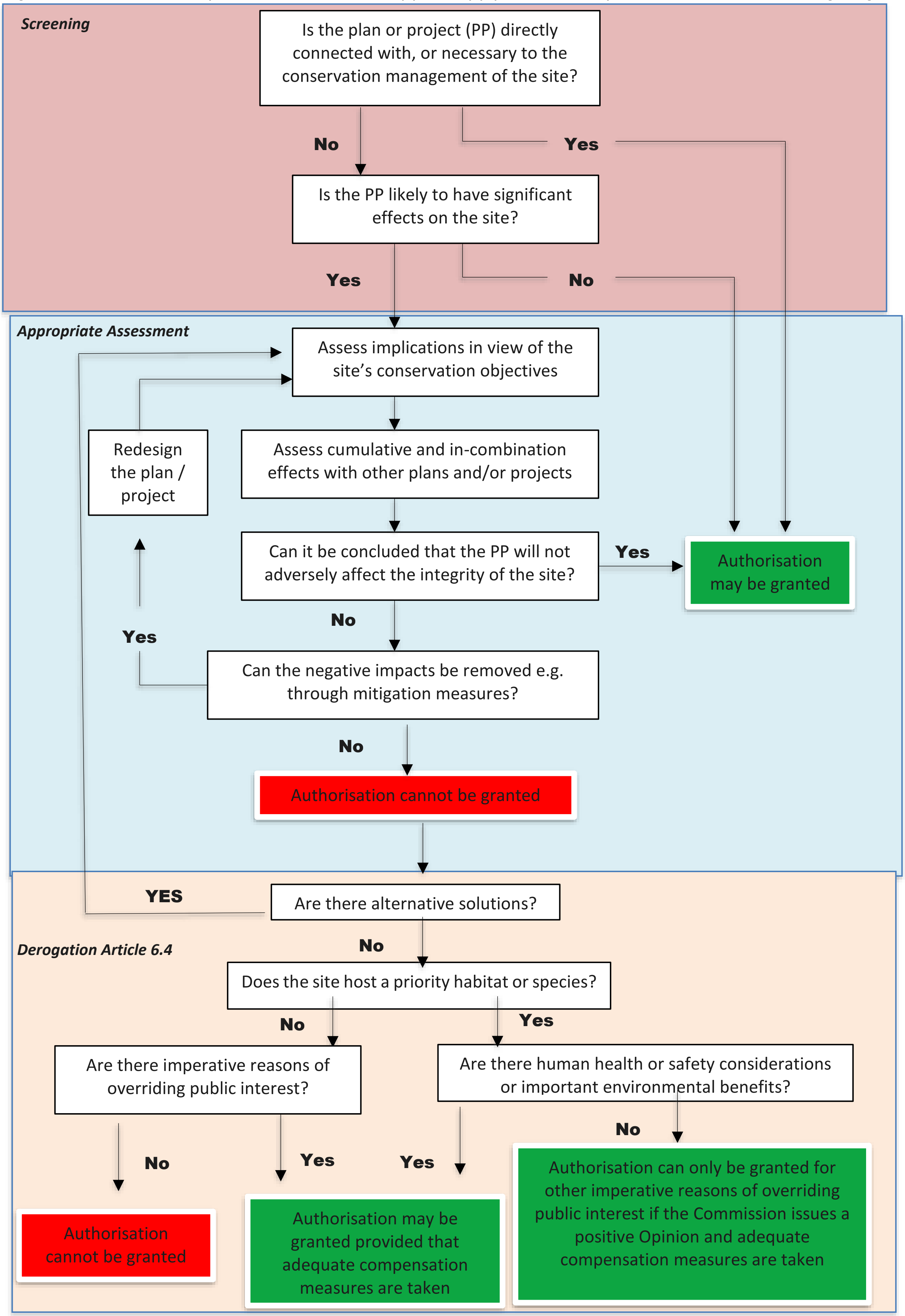
Each stage of the procedure is influenced by the previous stage. It is therefore essential to carry out the stages in the right order to apply Article 6(3) and (4) correctly. Figure 2-1 gives a simplified flow chart of this procedure.

Box 2-1 Article 6(3) and (4) of the Habitats Directive 92/43/EEC

Article 6(3). *Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public.*

Article 6(4). *If, in spite of a negative assessment of the implications for the site and in the absence of alternative solutions, a plan or project must nevertheless be carried out for imperative reasons of overriding public interest, including those of social or economic nature, the Member State shall take all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected. It shall inform the Commission of the compensatory measures adopted. Where the site concerned hosts a priority natural habitat type and/or a priority species the only considerations which may be raised are those relating to human health or public safety, to beneficial consequences of primary importance for the environment or, further to an opinion from the Commission, to other imperative reasons of overriding public interest.*

Figure 2-1 Flowchart of the procedure under Article 6(3) and 6(4) (based on European Commission methodological guide)



2.2.3.1 Screening

This stage examines the **likelihood of a project or plan having significant effects**, either alone or in combination with other projects or plans, upon a Natura 2000 site. If there is a possibility that it may have a significant effect on the site, an appropriate assessment will be needed under Article 6(3).

The screening is a pre-assessment stage. It is usually based on the best available information or expert opinion, rather than requiring detailed new evidence to be gathered. If sufficient information does not exist or is not readily available before a decision can be made, further information may be requested, and in some cases field visits may be useful.

Screening needs to be carried out at an early stage, i.e. before all the details of a plan have been decided, or before the design of a project begins but the location and general nature of a project is known. There are several **benefits of early screening**:

- It can reduce the risk of delays and additional costs later on, when examining applications for development consent.
- It allows early consultation between project promoters, competent authorities and other stakeholders with relevant data/expertise to make available best information to help assess the likelihood of significant effects.
- It enables the proponent of a plan or project to consider early on what next steps are required, without investing a significant amount of time and money.
- It enables the plan or project lead to identify and anticipate potential risks, both to Natura 2000 sites and to the plan/project itself, for example by choosing an alternative location or design for the plan/project to avoid or reduce potential effects or by collecting data to conduct an assessment without delay.

The **screening assessment** may differ for plans and projects, depending on the scale of the development concerned and the likely effects. It can be carried out in **four steps**.

Determining whether the project or plan is directly connected with or necessary to the management of a Natura 2000 site.
Description of the project or plan and its impact factors.
Identifying which (if any) Natura 2000 sites may be affected, considering the potential effects of the plan or project, alone or in combination with other plans or projects.
Assessing whether likely significant effects on the Natura 2000 site can be ruled out.

Box 2-2 indicates plans and projects in the field of wind energy to be subject to screening.

Box 2-2 Wind energy developments to be subject to screening

- A national or regional government spatial plan or programme that will influence development decisions with regard to wind energy projects
- The construction, operation and maintenance of a new wind energy project
- Decommissioning an existing wind energy project
- Refurbishing existing wind energy turbines or extending the operational life of an existing wind energy project (where the ecological effects of this extension have not been assessed).
- Repowering by installing new turbines on existing or new foundations at an existing wind energy development [under Article 2(10) of the revised Renewable Energy Directive (2018/2001)][40]

Identifying which Natura 2000 sites could be affected by the wind energy plan or project requires looking at all aspects of the project or plan that could have potential effects on any Natura 2000 sites in the area under the influence of the project/plan, taking into account the features (species, habitat types) for which the sites are designated. This should include:

[40] 'Repowering means renewing power plants that produce renewable energy, including the full or partial replacement of installations or operation systems and equipment for the purposes of replacing capacity or increasing the efficiency or capacity of the installation'.

- Any Natura 2000 sites geographically overlapping with any of the actions or aspects of the plan or project in any of its phases, or adjacent to them.
- Any Natura 2000 sites within the likely zone of influence of the plan or project. Natura 2000 sites located in the surroundings of the project or plan (or at some distance) that could be indirectly affected by the project actions or aspects. Typical examples related to wind energy developments are the construction and presence of access roads or the dewatering of wetlands or peatlands for constructing turbines.
- Natura 2000 sites in the surroundings of the project or plan (or at some distance) that host fauna that can move to the project area and then suffer mortality or other impacts (e.g. loss of feeding areas or home range).
- Natura 2000 sites whose connectivity or ecological continuity can be affected by the project.

The distance from the project or plan area at which Natura 2000 sites should be considered will depend on the characteristics of the plan or project and the distance at which its effects can be expected. Some projects or plans that do not directly affect Natura 2000 sites may still have a significant effect if they cause a barrier effect or prevent ecological linkages. This is typically the case for offshore wind farms potentially causing a barrier effect to foraging or migrating seabirds, even if wind farms are located at large distances from Natura 2000 sites designated for the protection of these seabirds.

Assessing whether a plan or project is **likely to have a significant effect** will have practical and legal consequences. Plans and projects that are considered as unlikely to have significant effects can be processed without reference to the subsequent steps of Article 6(3). However, the competent national authorities need to justify and record the reasons for reaching that conclusion.

However, **if the project or plan is likely to have a significant effect on a site, an appropriate assessment will need to be carried out.**

In case of doubt, i.e. if it cannot be excluded, on the basis of objective information, that a project or plan could have a significant effect on one or several Natura 2000 sites, either individually or in combination with other plans or projects, the plan or project needs to be subject to an appropriate assessment.

2.2.3.2 Appropriate assessment

The purpose of the appropriate assessment is to assess the implications of the plan or project against the site's conservation objectives, either individually or in combination with other plans or projects. The conclusions should enable the competent authorities to ascertain whether the plan or project will adversely affect the integrity of the site concerned. The focus of the appropriate assessment is therefore specifically on the species and/or the habitats for which the Natura 2000 site is designated.

The appropriate assessment can be coordinated with or be integrated in other environmental assessments, namely the environmental impact assessment (EIA) for projects and the Strategic Environmental Assessment (SEA) for plans and programmes (see 2.3).

As in the EIA and SEA process, the appropriate assessment usually involves the project or plan proponent submitting information in the form of an assessment report to the competent authority. If the appropriate assessment either identifies potential negative effects, or cannot rule out such effects, it also involves proposing mitigation measures to alleviate the effects identified.

It is the competent authority's responsibility to reach a conclusion about the effects of the project or plan on the integrity of a Natura 2000 site.

The assessment process includes gathering and assessing information from multiple stakeholders, including national, regional and local nature conservation authorities, and relevant NGOs. It is imperative that the assessment of the plan or project is based on good quality, objective information and reliable data, using appropriate and robust scientific methodology. The competent authority can then use the information submitted by the project or plan proponent as the basis for consultation with internal and external experts and other stakeholders. The competent authority may also need to request further information to ensure that the final assessment is as comprehensive and objective as possible. The procedure should include providing information to the public and enabling public participation.

Conducting the appropriate assessment involves the following steps:

- gathering information on the plan or project and on the Natura 2000 sites concerned;
- assessing the implications of the plan or project against the site's conservation objectives;
- determining whether the plan or project can have adverse effects on the integrity of the site;
- considering mitigation measures (including monitoring).

These steps may need to be implemented iteratively, with some steps repeated in response to the results of other steps.

The assessment must identify all aspects of the plan or project that can, either individually or in combination with other plans or projects, affect the site's conservation objectives, in the light of the best scientific knowledge in the field. Appraisal of the effects must be based on objective and, if possible, quantifiable criteria to give as precise as possible an estimate. The assessment must also clearly state the basis of these predictions and record it in the corresponding assessment report.

The assessment should take account of the possible impacts of the whole project or plan in question, including all the activities it comprises in the different phases (preparation, construction, operation and, where relevant, decommissioning). It requires identifying and differentiating by type of impact, including direct and indirect effects, temporal or permanent effects, short- and long-term effects and cumulative effects. The appropriate assessment involves looking at all aspects of the plan or project likely to have significant effects on the Natura 2000 site at the screening stage. In this context, each aspect of the plan or project should be examined in turn and its potential effects should be considered in relation to each of the species or habitat types for which the site has been designated. Then, the assessment should look at the effects of the different features within the plan or project as a whole, and in relation to each other, to identify interactions between them.

The assessment carried out under Article 6(3) of the Habitats Directive must contain complete, precise and definitive findings and conclusions, in the light of the best scientific knowledge in the field. It should be capable of removing all reasonable scientific doubt as to the effects of the works proposed on the protected site concerned (see Appendix C for good practice approaches to overcome typical uncertainties encountered in assessing wind energy developments). The conclusions of the appropriate assessment must clearly relate to the integrity of the site. If the assessment concludes that there will be adverse effects on the integrity of the site, it should clarify for which aspects, following mitigation measures, may there be residual adverse effects. This will be important if the plan or project is considered using the derogation process under Article 6(4).

When the appropriate assessment is completed, it is considered best practice to produce a report that:

- describes the project or plan in sufficient detail for members of the public to understand its nature, scale and objectives;
- describes the baseline conditions of the Natura 2000 site;
- identifies the adverse effects of the project or plan on the Natura 2000 site;
- explains how those effects will be avoided or sufficiently reduced through mitigation;
- sets out a timescale and identifies the mechanisms through which the mitigation measures will be secured, implemented and monitored.

The result of the appropriate assessment and the conclusions of the report should be part of the authorisation process or any other decision taken on the plan or project under consideration.

It is for the competent authorities, in the light of the conclusions made in the appropriate assessment on the implications of a plan or project for the Natura 2000 site concerned, to approve the plan or project. This decision can only be taken after they have made certain that the plan or project will not adversely affect the integrity of the site. That is the case where no reasonable scientific doubt remains as to the absence of such effects. Where doubt remains as to the absence of adverse effects on the integrity of the site linked to the plan or project being considered, the competent authority must reject the application for authorisation.

2.2.3.3 Derogations under Article 6(4)

Competent authorities may only approve plans or projects for which the appropriate assessment could not rule out adverse effects on the integrity of the sites concerned by issuing a derogation under Article 6(4). These provisions set three key requirements that must be met and documented:

- the alternative put forward for approval is the least damaging for habitats, for species and for the integrity of the Natura 2000 site(s), regardless of economic considerations, and no other feasible alternative exists that would not adversely affect the integrity of the site;
- there are imperative reasons of overriding public interest, including 'those of a social or economic nature';
- all compensatory measures necessary to protect the overall coherence of Natura 2000 are taken.

Detailed information on the provisions of this article can be found in the European Commission's Guidance document on the provisions of article 6(3) and 6(4) of the Habitats Directive[41].

2.2.4 Species protection provisions

The information in this chapter is mainly based on the European Commission's Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC[42].

The second set of provisions under the Nature Directives concerns the protection of certain species across their entire natural range within the EU, i.e. both within and outside Natura 2000 sites. The species protection measures apply to species listed in Annex IV to the Habitats Directive and to all wild bird species in the EU. The exact terms are laid down in Article 5 of the Birds Directive and Articles 12 (for animals) and 13 (for plants) of the Habitats Directive.

In essence they require Member States to prohibit:

- the deliberate capture or killing of species;
- their deliberate disturbance during breeding, rearing, hibernation and migration;
- the deterioration or destruction of breeding sites or resting places;
- the deliberate destruction of nests or eggs, or the uprooting or destruction of protected plants.

Derogations to the species protection provisions are only allowed in limited cases – such as in the interest of public health and safety, or for other imperative reasons of overriding public interest – provided that there is no other satisfactory alternative and that the consequences of these derogations are not incompatible with the overall aims of the Directives. The conditions for applying derogations are set out in Article 9 of the Birds Directive and Article 16 of the Habitats Directive.

The species protection provisions are highly relevant to wind energy developments. They aim, for example, to ensure that any new developments do not cause destruction of the breeding and resting places of any species listed under Annex IV to the Habitats Directive or the killing or injury of any wild bird, unless a derogation has been granted by the competent authorities in accordance with the Directives.

2.3 Streamlining with the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) processes

In addition to the appropriate assessment under Article 6(3) of the Habitats Directive, wind energy plans or projects will often be subject to the SEA Directive[43] or the EIA Directive[44].

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[41] https://ec.europa.eu/environment/nature/natura2000/management/docs/art6/natura_2000_assess_en.pdf
[42] Available at https://ec.europa.eu/environment/nature/conservation/species/guidance/index_en.htm
[43] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.
[44] Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment, as amended by Directive 2014/52/EU.

Integrating and coordinating the environmental assessment procedures set out in these pieces of EU legislation improves the efficiency of administrative processes. It is important to understand the similarities and differences in the provisions of each Directive.

Under Article 2(3) of the EIA Directive, Member States must ensure that projects for which the obligation to carry out assessments of the effects on the environment arises simultaneously from the EIA and the Habitats Directives, are subject to coordinated and/or joint procedures of either one or both combined. Coordinating or combining the environmental assessment procedures applied to a project to avoid overlaps and redundancy, seeking synergies and minimising the time needed for authorisation, is known as 'streamlining'. The Commission has issued a guidance document on streamlining environmental assessments referred to under Article 2(3) of the Environmental Impact Assessment Directive[45]. The SEA Directive includes similar provisions for streamlining environmental assessments.

In all cases, it is essential that the information needed for each assessment and its conclusions remain clearly distinguishable and identifiable in the environmental impact assessment report, so that they can be differentiated from general EIA or SEA information. This is necessary as there are a number of important distinctions between the EIA/SEA and the appropriate assessment procedures, in particular the fact that the results of the appropriate assessment are binding for the authorisation of a plan or project. This means that an SEA or an EIA cannot replace an appropriate assessment as neither procedure overrides the other.

[45] Commission notice — Commission guidance document on streamlining environmental assessments conducted under Article 2(3) of the Environmental Impact Assessment Directive (Directive 2011/92/EU of the European Parliament and of the Council, as amended by Directive 2014/52/EU) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2016.273.01.0001.01.ENG&toc=OJ:C:2016:273:TOC).

3. GENERAL APPROACH AND PRINCIPLES DURING SCREENING AND APPROPRIATE ASSESSMENT

This aim of this chapter is to provide guidance and good practices on some general issues that can arise during the screening and appropriate assessment procedures, such as assessing significance of the effects, the scoping procedure and setting a baseline. It also covers issues of uncertainty, cumulative effects and stakeholder consultation.

3.1 Significance of the likely effects

Article 6(3) of the Habitats Directive refers to the need to assess the likelihood of a plan or project having significant effects on a Natura 2000 site. The screening process assesses whether it is likely to have a significant effect on the site. If significant effects cannot be excluded with certainty, an appropriate assessment is necessary. The appropriate assessment assesses the likely effects on the Natura 2000 site against its conservation objectives and whether implementing the plan or project may or will adversely affect the integrity of the site.

One of the major challenges faced when undertaking an assessment of a plan or project is how to understand and determine when an effect is significant or not.

It is necessary first to explore the type and extent of effects ('significant effect'), and then to explore the causes likely to create such effects ('likely to have … either individually or in combination'). Determining whether a plan or project is likely to have a significant effect will have practical and legal consequences. Therefore, when a plan or project is proposed, it is important firstly that this key issue is considered, and secondly that the consideration can stand up to scientific and expert scrutiny. The safeguards set out in Article 6(3) are triggered not by a certainty but by a likelihood of significant effects. Mitigation measures cannot be taken into account at this stage. Transboundary effects are also to be considered (European Commission, 2019).

Significance will vary depending on factors such as magnitude of effects, type, extent, duration, intensity, timing, probability, cumulative effects and the vulnerability of the habitats and species concerned.

Effects typically considered when assessing significance include the following:

- **Direct loss of habitat**: a reduction of habitat coverage as a result of physical destruction (i.e. due to its removal or the placement of construction materials or sediments); loss of breeding, foraging, resting areas for species.
- **Habitat degradation**: a deterioration or reduction of habitat quality, e.g. as a result of reduced abundance of the characteristic species or altered community structure (species composition); deterioration of breeding, foraging, resting areas for species.
- **Habitat fragmentation**: an alteration of distribution patches of relevant habitats and species, e.g. a contiguous area of habitat split into two or more small, isolated areas, causing a barrier between habitat fragments.
- **Disturbance of species**: a change in the environmental conditions (e.g. noise, frequency of people and vehicles, increase in suspended sediment or dust deposition); e.g. disturbance may cause displacement of species individuals, changes in species behaviour, mortality risk.
- **Indirect effects**: an indirect change to the quality of the environment (including hydrology).

For wind energy developments, typical additional types of effects are the barrier effect and the collision risk.

Sources of information to determine the significance of effects may include evidence from similar operations affecting sites with similar conservation objectives and expert opinions based on available evidence. However, the assessment must look at the local circumstances on a site-by-site basis, as what may be significant for one site may not be so for another.

The notion of what is 'significant' needs to be interpreted objectively. The significance of effects should be determined in relation to the specific features and environmental conditions of the protected site affected by the plan or project, taking particular account of the site's conservation objectives and ecological characteristics (European Commission, 2019).

An assessment of significant effects must be based on good science (including best available methods and knowledge) and reliable data, be precautionary and, if appropriate, it should take into account the opinion of stakeholders, such as NGOs, nature conservation agencies or researchers.

The assessment must apply the principle of proportionality, be compatible with the precautionary principle and take into account:

- the nature, size and complexity of the plan or project;
- the expected effects, and
- the vulnerability and irreplaceability of the affected EU-protected habitats and species.

Taking a proportionate approach means assessing the significant effects on all the affected EU-protected habitats and species and effectively avoiding or reducing the effects, while not entailing excessive cost (Smeeton & George, 2014).

Rulings issued by the Court of Justice of the EU have on a number of occasions considered what effects arising from plans or projects constitute significant effects. In the context of the EIA Directive, it recently (2017) considered significant effects as potential effects on species which are protected by the Habitats Directive (or by national law)[46].

More detailed information on how to assess significance can be found in Chapters 4.2 (onshore) and 6 (offshore) of this guidance under the specific sub-chapters for habitats and the different species groups.

3.2 Establishing the content, the area and timeframe of the assessment (scoping)

Assessments will require the collection of baseline data specific to the context of the individual plan or project. It is important that a competent national authority for a plan and a developer of a project engage with key stakeholders to assess the scope of the assessment on the basis of expert opinion. The agreed scope should define which information to include in the assessment in relation to EU-protected habitats and species, Natura 2000 sites, pathways and effects, as well as plans and projects that could act in combination (see Chapter 3.4 on cumulative effects).

It may take over 12 months to establish the baseline conditions for wind energy developments. For example, to account for variations in factors such as weather conditions and food availability that are known to have a strong influence on the abundance of highly mobile species such as seabirds, monthly baseline surveys may be required for a continuous 24-month period. For sedentary species, or habitats that are not highly dynamic, baseline surveys over a single 12-month period may be adequate to cover seasonal variation.

In every case, the timescales for a wind energy development factor in the need to collect baseline data over a sufficient period of time, covering seasonal aspects of behaviour (breeding, migration, hibernation) as appropriate. Baseline data should record the environmental conditions in the scenario that the plan or project is not implemented, i.e. before any pre-construction or construction activities that would measurably change the baseline conditions. The plan or project timescale must also take into account the fact that ecological data may only be valid for a certain period of time and competent national authorities may only accept the validity of data for the purposes of an SEA, EIA or appropriate assessment if they are collected within a certain time prior to the assessment[47].

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[46] C-461/17, Holohan and Others, ECLI:EU:C:2018:883, [2018] Reports of Cases (Court Reports — general); recalling 'judgment of 24 November 2011, Commission v Spain (Alto Sil/Spanish brown bear) and C-404/09, EU:C:2011:768, paragraph 86'.

[47] The UK bat survey guidelines (Collins, 2016) state that the length of time during which survey data remain valid should be decided on a case-by-case basis and depends on a number of questions, as follows:
- Were the original surveys carried out according to good practice guidelines?
- Were the original surveys constrained in any way (in terms of timings, weather conditions, equipment used, number of surveyors, surveyor expertise, etc.)?
- Do the results of the original surveys support the original conclusions and are these still relevant?

Chapter 4.2 (onshore) and chapter 6 (offshore) present reviews of the likely significant effects arising from wind energy development on EU-protected species and habitats. This includes looking at the key parameter of distance (within which effects may be measurable) and at the ranging behaviour of mobile species.

The effects of a development, such as wind turbines, must be considered across its whole life cycle. These effects can be far reaching and could affect EU-protected habitats and species that are distant from the plan or project. The study area (spatial frame of reference) must therefore be defined to encompass the whole geographic area within which all plan or project activities and effects are likely to occur.

In the light of the effects likely to occur as a result of the plan or project, the study area may be expanded to include environmental features at a wider landscape, seascape or ecosystem scale, e.g. a river catchment. The study area may change during the assessment process if additional information is received or is required to support the assessment, mitigation planning, or if long-term monitoring requires control sites (Gullison *et al.*, 2015).

It is also necessary to define the timeframe (temporal frame of reference) of the assessment. The effects on EU-protected species may occur for a period of time after the plan or project starts and/or finishes (Box 3-1). The timeframe should be long enough to take into account past, present and likely future baseline conditions, the total period of time over which effects are likely to be generated, the predicted effects of climate change on environmental conditions and EU-protected habitats and species as well as any foreseeable future developments, with reference to spatial plans and/or expert opinion.

Lastly, when defining the space and timeframe, the assessment should also factor in potential cumulative effects (see Chapter 3.4).

Box 3-1 Example of scenarios requiring an extended timeframe

Example 1. Long-lived species, such as large migratory birds of prey, that return to Europe and breed only after three or four years of age. The loss of immature individuals through wind turbine collision mortality soon after fledging or on migration may only be measurable in the breeding population when the breeding adults are not replaced by returning birds of breeding age. This may occur only after three to four years from the project becoming operational but will remain after the project has ceased operation.

Good practice:

With reference to the conservation objectives of the Natura 2000 site, assess the population consequences of wind turbine collision mortality from when the plan or project commences to when the effect is predicted not to occur anymore.

Example 2. Climate change-induced sea level rise reduces the extent of a coastal habitat within the next 25 years.
The loss of a coastal habitat under the footprint of wind turbine foundations can be predicted at the time of construction. The significance of habitat loss over a 25-year operational phase of the plan or project may be considerably greater when the loss of coastal habitat to sea level rise is taken into account. This is especially important if implementing the project may prevent climate change-related management actions from being taken e.g. managed realignment of the coastline.

Good practice:

With reference to the conservation objectives of the Natura 2000 site, assess the loss of habitat from the footprint of the plan or project in combination with scientifically justifiable predictions of habitat loss or gain within the Natura 2000 site under different scenarios of climate change-induced sea level rise.

Example 3. Development of a reef community on turbine foundations in marine waters.
Establishing communities on artificial structures, and other marine species in response, is a dynamic process that can take many years and is complicated by factors such as reduced fishing pressure. Such effects are likely to develop over

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• Has the nature of the site or the surrounding area changed since the original surveys (e.g. has a structure deteriorated and become less suitable for a roost or has human occupation ceased and the structure become more suitable for a roost)?
• Are additional surveys likely to provide information that is material to a decision (such as a planning consent), the design of mitigation measures, or specific advice relating to a proposed activity?

the entire operational phase of a wind energy development plan or project. If foundations and/or material such as rock armour are left in situ after decommissioning then the effects, whether positive or negative, may also last for perpetuity.

Good practice:

Identify potential trophic consequences of reef development in relation to the ecological characteristics or function of the Natura 2000 site and assess the likely effects. Conduct monitoring, not just to describe colonisation, but to evaluate the consequences for groups such as marine mammals, so that informed decisions can later be made about decommissioning.

Consider whether the development of benthic communities[48] on emplaced substrates (e.g. rock armour) makes a positive contribution to biodiversity and ecosystem function or to the degradation of natural habitat. This will depend in part on the historical context, e.g. whether there has been past loss of hard substrate habitats.

Consider monitoring invasive non-native species that may colonise hard structures, because they tend to colonise new substrate faster than native species.

3.3 Setting a baseline

The required baseline information has to be proportional to the needs of the assessment. Thus, baseline information for screening will be less detailed than the baseline information for the appropriate assessment. It may often be possible to base the screening decision on published material and consultation with relevant nature conservation agencies.

The baseline describes the ecological context of the plan or project location, the Natura 2000 sites concerned and the links between the plan or project and those sites. Box 3-2 gives examples of relevant baseline ecological information. Box 3-3 gives examples of existing information sources and additional data from surveys that form the basis of every appropriate assessment[49].

Box 3-2 Examples of relevant baseline ecological information

- Population size and trends, degree of isolation, seasonality, age class structure and conservation status[50]
- Habitat area, degree of fragmentation and isolation and conservation status
- Biological and ecological relationships between habitats and species (e.g. home-range analysis)
- Land/sea management practices, for example, crop rotation, seasonal vegetation burning and no-take fishing zones
- Environmental characteristics that link the plan or project location and Natura 2000 sites, e.g. rivers or tidal currents

Box 3-3 Examples of key information sources for impact assessments

- Natura 2000 standard data forms

The Standard Data Form, which is available for each Natura 2000 site, contains information on the EU-protected species and habitat types for which the site has been designated and provides a broad assessment of the condition of each species or habitat type on that site (scored from A to D).
It provides information about surface area, representativeness and conservation status of the habitats present in the site, as well as an overall assessment of the value of the site for conservation of the natural habitat types concerned.

[48] the community of organisms that live on, in, or near the seabed, river, lake, or stream bottom, also known as the benthic zone
[49] The typical level of information considered at each stage of the appropriate assessment process is summarised in Appendix C.
[50] For a number of taxa such as bats and marine mammals, this can only be done to the extent that this is possible. For instance, for bats, population size and age class structure are critical measures and a lack of data prevents sensible assessments of most sites at present. However, calculations of population size would require making significant increases in investment by wind-farm developers as specific additional baseline collection techniques would be necessary, such as roost location by radio-tracking, counting of animals, trapping, etc. It is expected that more information will gradually become available over the next years (see e.g. a UK-wide survey (https://www.bats.org.uk/our-work/national-bat-monitoring-programme/british-bat-survey).

For the species present in the site, it provides information on their populations, status (resident, breeding, wintering, migratory) and on the site value for the species in question.
It also includes relevant contextual information about the site, including:

- general site characteristics, quality and importance;
- vulnerability (pressure on the site from human and other influences and the fragility of habitats and ecosystems);
- all human activities and natural process that may have an influence, either positive or negative, on the conservation and management of the site;
- the management body responsible for the site;
- site management plans and practice, including traditional human activities;
- a map of the site.

• Site management plans

When available, Natura 2000 management plans can provide information on the site's conservation objectives, the location and status of the species and habitats occurring in the site, the threats to them and the conservation measures required to improve their conservation status. This can be useful for the screening stage and for the appropriate assessment.

• Natura 2000 Viewer (http://natura2000.eea.europa.eu/) and the Natura 2000 public database http://ec.europa.eu/environment/nature/natura2000/data/index_en.htm
• Wildlife sensitivity maps
• Current and historic maps and aerial imagery, geological and hydrogeological survey information, information sourced from competent national authorities, nature conservation agencies, NGOs, completed SEAs, EIAs and appropriate assessments, wind farm databases and other organisations with relevant experts[51]
• EU-funded research project data and reports as well as other research publications and databanks from academia, NGOs or industry. As an example, telemetry data e.g. from LIFE projects can be of great use. An interesting databank is Movebank[52] (https://www.movebank.org/)
• Relevant plans, current and historical maps, existing geological and hydrogeological survey information as well as any existing ecological survey information available from industry organisations, developers, landowners, site managers or nature conservation agencies and organisations
• Strategic and project level environmental reports and environmental impact assessment reports, appropriate assessment reports and other documentary evidence where plans or projects have been assessed in the past
• Additional field surveys of habitats and/or species if existing data on (e.g. habitat area or population size) don't provide sufficient level of detail (see Box 3-2)

There are three key steps to setting a relevant baseline:

Firstly, it is important to start by conducting a *desk-based review*. This review will identify the EU-protected habitats and species, for which the Natura 2000 site(s) have been designated, within the study area. It includes compiling and evaluating existing information on these habitats and species as well as environmental and ecological features located outside the designated site boundary that may be linked to the conservation objectives of the site(s).

Secondly, it is considered good practice, especially for onshore projects, to undertake a *reconnaissance site visit* by a suitably qualified and experienced ecologist. The reconnaissance site visit can involve, for example, discussions with local land users and land managers to better understand the seasonal practices that may influence the biodiversity on the site (e.g. the use of fire to burn off grassland in autumn in order to produce fresh growth the following spring). Box 3-4 summarises the key points to check in a reconnaissance site visit.

Box 3-4 Checklist for reconnaissance site visit for onshore wind developments

• Is the baseline information up-to-date? For example, has there been a reduction in the area of habitats that are the reason for designation as a result of coastal erosion, are there new areas of supporting habitat created by land management practices such as forestry, or is there any indication that the number of breeding pairs of a species that is the reason for designation at a seabird colony has changed?
• Are there new areas that are of significance to the EU-protected habitats and species? For example, are there new roost sites or foraging areas for birds/bats within or beyond the boundaries of a Natura 2000 site?

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[51] See for example, The Wind Power https://www.thewindpower.net/store_windfarms_view_all_en.php and 4C Offshore https://www.4coffshore.com/offshorewind/
[52] In Greece, many developers or consultants already use this online database during the EIA process (or even before it). The 'Tracking Data Map' field includes several projects with available data (some of them are available online; for others, one needs to contact the administrator). Data refer to locations/flights of birds fitted with GPS transmitters.

- Is the study area appropriate? On the basis of the above, does it cover the entire area that could be affected by the plan or project?
- Have local stakeholders been consulted? Consultation may be particularly important where there is significant seasonal variation in biodiversity abundance and/or where there are seasonal land management practices such as vegetation burning or hunting.
- What are the constraints to survey work? For example, is there safe access, clear sightlines for visual surveys and will seasonal land management practices bias results? The reconnaissance site visit and consultation with local stakeholders will provide an opportunity to establish what the constraints will be and identify suitable survey methodological approaches and locations from which to collect data.

Thirdly, where knowledge gaps are identified or where data are not up-to-date, surveys to collect missing or up-to-date information must be planned and undertaken by qualified and experienced ecologists. Assessing whether the data are up-to-date should be based on the type of survey, whether previous surveys were undertaken in optimal conditions or season, and whether environmental conditions have changed. It is good practice to collect data within a minimum of one to three years from the assessment. The timeframe for collecting baseline data must be decided on a case-by-case basis, taking into account the general paucity of existing data, the full annual life cycle of the species as well as existing knowledge on variation between years (e.g. where the migration of species can be affected by weather conditions).

When determining the length of time over which survey data need to be collected, it is also important to consider how the data will be analysed (see also Chapter 7).

It is good practice to ensure that pre-construction surveys are designed to allow comparison with the results of post-construction monitoring, and that methodologies are accurately recorded in sufficient detail to allow continuity of method and analysis, even if staff change (as is often the case with multiannual projects).

Reference to ecological survey methods is included in the discussion of potential impacts in Chapter 4.2 (onshore) and Chapter 6 (offshore).

Further guidance on conducting baseline surveys is provided in European Commission's methodological guidance on Articles 6(3) and (4) (EC, 2019), in 'Good Practices for the Collection of Biodiversity Baseline Data' (Gullison *et al*, 2015).

3.4 Assessing cumulative effects

3.4.1 Which activities to take into account?

A wind energy plan or project can act in combination with other plans and projects and result in cumulative effects on EU-protected habitats or species.

Cumulative environmental effects can be defined as effects on the environment caused by the combined action of past, current and future activities. Although the effects of one development may not be significant, the combined effects of several developments together can be significant. Cumulative effects are very relevant to wind energy deployment, given the continuously growing number of applications for wind energy production and the expected increase in capacity over the coming years (see Chapter 1 on Wind energy policy).

Considering that the assessment of cumulative effects of plans and projects is a requirement under Article 6(3) of the Habitats Directive as well as under the SEA and EIA Directives (Annex III and IV), the key principles for this assessment relating to wind energy development are described below.

First of all, under Article 6(3) the 'in combination' **provision applies both to screening and to the appropriate assessment**.

Secondly, the 'in combination' provision applies to plans or projects that are **completed, approved but uncompleted**, or proposed. In addition to the effects of the plans or projects that are the main subject of the assessment, it may be appropriate to consider the effects of already completed plans and projects. Although already completed plans and projects are themselves excluded from the assessment requirements of Article 6(3), it is still important to take them into consideration when assessing the effects of the current plan or project in order to determine whether there are any potential cumulative effects arising from the current project in combination with other completed plans and projects. The effects of completed plans and projects would typically form part of the site's baseline conditions at this stage (see chapter 3.3). Plans and projects that have been approved in the past but have not yet been implemented or completed should be included in the in-combination provision. As regards other proposed plans or projects, on grounds of legal certainty it would seem appropriate to restrict the 'in combination' provision to plans that have been proposed, i.e. for which an application for approval or consent has been submitted (see chapter 4.5.3).

In addition, it is important to note that the assessment of cumulative effects is **not restricted to the assessment of similar types of plans or projects** covering the same sector of activity (e.g. a series of wind farms). The assessment should include all types of plans or projects that could, in combination with the wind farm or wind energy plan under consideration, have a significant effect.

Similarly, the assessment should consider the cumulative effects not just between projects or between plans but also between projects and plans (and vice versa). For example, a new project to build a wind farm near a Natura 2000 site may on its own not adversely affect the site, but when considered in combination with an already approved transport infrastructure project crossing the same area, these effects may become significant enough to adversely affect the site. By contrast, a plan may have no significant effect on Natura 2000 sites on its own but may be assessed differently if considered in combination with an already proposed or authorised major development project not included in that plan (see chapter 4.5.3).

Defining the appropriate spatial scope in the context of cumulative effects might be challenging, in particular when assessing effects on migratory birds and bats. As mentioned under Chapter 3.2 (scoping) it is recommended that competent authorities and developers engage with stakeholders to define the scope of the assessment.

A key challenge in cumulative impact assessment is understanding how effects accumulate, what the important ecological thresholds are and when these will be exceeded. This is indeed a complex issue and it needs to be acknowledged that there are many uncertainties. Moreover, all uncertainties related to the challenge of assessing significance (see 3.5) are also relevant to the cumulative impact assessment but now the complexity is even higher. For example:

- There is still very little known about the effects at population level. Cumulative impact assessment is limited by basic knowledge of population dynamics (e.g. how much space do particular species need? Can they easily find other places for foraging?). In particular for offshore wind energy developments, population scale effects on bat, bird and marine mammal populations are hard to investigate.
- It is difficult to understand the overall extent of pressure on receptors (for example fishing, pollution, noise etc.). It is challenging to consider different pressures resulting from different activities cumulatively in one area.
- It is hard to predict how different species will use the landscape or seascape when there are many different projects.
- It is not always clear how to deal with small-scale projects when nearby there is a large-scale project that would automatically dominate all notions of cumulative impact. Nonetheless, it is often forgotten that projects that are screened out due to absence of significant effects always contribute to cumulative effects.

Another reason that adds to the complexity of making cumulative impact assessments is the **lack of data**, not only on effects (e.g. mortality, displacement) but also on the activities to be considered:

- Post-monitoring data are often not stored in a public database and are rarely processed in a way that allows useful information (e.g. patterns, effectiveness of measures) to feed into future plan or project assessments.
- In Member States without national guidance on how to conduct post-monitoring, there is an issue of incompatible methodologies (and the same applies across national boundaries).
- There is a general lack of public databases giving a spatial overview of existing and planned activities and related information on their main characteristics (e.g. number of wind turbines, height of turbines, exact location, link to the geographic information systems (GIS), etc.).

Lastly, a common challenge related to making cumulative impact assessments is how to **attribute the 'burden' of cumulative effects** when project developments take place sequentially. The current main approach is based on the 'first come, first served' principle, which means that the last project takes into account all effects of all previous projects. As a consequence, plans and projects that are additional to those already approved in the same area face an increased risk to be rejected due to the increased risk of significant effects.

Despite all these challenges, potential cumulative effects should be assessed using sound baseline data and should not rely only on qualitative criteria. They should also be assessed as an integral part of the overall assessment and should not be treated merely as an 'afterthought' at the end of the assessment process.

Research into developing solid approaches to cumulative impact assessment is intensifying, mainly in relation to offshore wind. It can be expected that more guidance will become available over the next couple of years.

3.4.2 Recommended approach related to assessing cumulative effects in the wind energy sector

The chapter below sets out recommended approaches on how to deal with the above-mentioned challenges. They were identified on the basis of extensive stakeholder consultation in all EU Member States as part of this project.

- Wind energy development plans or projects should be considered jointly with other activities that might have effects on the same EU-protected species and habitats. For instance, the development of the energy grid infrastructure has similar types of impacts on birds. Furthermore, the assessment should take into account not only existing developments, but also plans or projects that are completed, approved but uncompleted, or proposed (see 3.4.1). Having available data on these other activities and their impacts is therefore crucial. Information from post-monitoring of operating wind farms could, for instance, be used for mortality assessments of the newly planned wind farm.
- Project developers should consider cumulative effects as an integral and meaningful part of the overall assessment. Early engagement of developers with competent authorities, e.g. in the context of scoping or data gathering, will enhance the quality of such assessments. However, in some cases, it might be appropriate to shift the responsibility for preparing cumulative impact assessments from project developers to the government, as they have the best overview and knowledge of other activities in large areas. Or at least the government could collect all relevant information and provide it to the project developers and consultants. Similarly, creating a national or regional database would greatly facilitate the overview of different activities. Ideally, the database would include a dynamic map enabling a search of all projects, including those still at the planning phase. This would improve the quality of decision-making.
- The spatial scope should encompass the geographic area within which all plan or project activities and their accumulated effects are likely to have implications on the conservation objectives of the Natura 2000 sites in question. The principle of proportionality should be applied to ascertain the scale of effort needed to complete a cumulative effects assessment appropriate to the requirements of Article 6(3) (see good practice Case study 3-1). For large-scale wind development plans that are mainly offshore, but can be onshore as well, it is recommended to apply a transboundary approach.
- The assessment of cumulative effects in spatial planning is fundamental to identifying 'areas suitable for low-ecological-risk deployment' in accordance with the revised Renewable Energy Directive. Cumulative effects are better addressed in SEAs and related appropriate assessments, in particular with regard to marine spatial planning as these spatial plans cover all marine activities.
- It is worth looking at existing good practice in dealing with uncertainties in cumulative impacts assessment. The Netherlands has developed a 'Framework Ecology and Cumulation' process (Case study 3-2), to support the development of offshore wind energy. Applying this framework to all planned wind turbines in a certain marine area avoids the 'first come, first served' approach, which means that that the latest developments carry the highest risk of rejection due to cumulative effects.

Case study 3-1 Guidance on assessing the spatial scope of cumulative impact assessment related to bird populations in Flanders (Belgium)

Some Member States or regions provide specific guidance on issues related to cumulative impact assessment. Flanders (Belgium) has developed guidelines for dealing with environmental risks and monitoring related to onshore wind energy developments and birds and bats. They indicate that it is not necessary to look at the population/conservation status beyond national borders. The (cumulative) effects of power lines or wind farms on important seasonal migration routes of birds is assessed at sub-regional (local) flyway scale in the Flanders region (estimated part of the population that migrates within this flyway where the new power line or wind farm is planned).

The following approach is applied:

- For individual project proposals, it is unrealistic to assess all possible cumulative effects, mainly because the necessary information is not available on the scale of the assessment, even at local/sub-regional scale (the regional scale is Flanders, the local scale is 'sub-regional'). But it is possible to at least assess the cumulative effects of similar recent projects and plans (wind farms, power lines) with the methods described in the guidance (estimated additional mortality threshold of 1-5% of the normal annual mortality in the population (current natural and anthropogenic mortality, see 5.4.2))
- To keep cumulative impact assessment pragmatic, the effects of each individually planned power line and wind farm is assessed on a local or regional scale. In most cases, the local scale is used. For example, for wintering ducks, the sub-regional scale consists of all ducks in the areas that are ecologically connected throughout the winter season. An assessment at a larger scale is possible when the cumulative effects can be calculated sufficiently. Moreover, to assess the possible significant effects on the integrity of a Natura 2000 site (or network of sites), the population needs to be assessed on a smaller scale. In the future, a model on a regional scale may be built to regularly assess the current cumulative effects of all wind farms in Flanders, preferably based on monitoring results of operational wind farms. The output of the model could be used to improve the local or sub-regional thresholds.

Sources: Everaert J. (2015). *Effecten van windturbines op vogels en vleermuizen in Vlaanderen. Leidraad voor risicoanalyse en monitoring. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2015* (INBO.R.2015.6498022). Instituut voor Natuur- en Bosonderzoek, Brussels.
Everaert J. (2017). Dealing with uncertainties in bird and bat population impact assessments for individually planned wind farms. Presentation at the Conference on Wind energy and Wildlife impacts (CWW), 6-8 September 2017, Estoril, Portugal.

Case study 3-2 Dealing with cumulative impact assessment for offshore wind in The Netherlands

The Netherlands has decided that offshore wind energy should generate a total of 4,450 MW of electricity by 2023, and a total of 11,500 MW between 2024 and 2030. At the time of writing (2019), only 1,000 MW has been built or is under construction. The applicable decisions are recorded in the 'Roadmap Offshore Wind the Netherlands', including a detailed spatial mapping and a timeframe for building the new wind farms.

As the cumulative effects are expected to be substantial, the Dutch government has developed a 'Framework Ecology and Cumulation' to support the development of offshore wind energy. This framework provides guidance on how to calculate the cumulative effects. It is applied to all spatial decisions related to offshore wind, including EIA and appropriate assessment. It is a living document that is continuously adapted on the basis of new scientific insights and new data. It consists of a main report with the methodological guidance and a suite of sub-reports with specific focus on receptor groups (birds, bats, marine mammals). These sub-reports provide more detailed methodologies and models as well as the predicted outcomes based on the implementation of the Roadmap. A management summary has recently been added, providing a summary of each sub-report and the conditions to fulfil when implementing the Roadmap for 2030.

The framework is fed by the outcomes of research programmes developed since 2010 to bridge knowledge gaps.

The recently updated calculations not only include the projected wind energy developments in the Dutch part of the North Sea but also the planned wind energy developments in other North Sea territories.

The concept of 'potential biological removal' (PBR) is used as an acceptable threshold to assess the cumulative effect of wind energy developments on a number of bird and bat species, as well as on porpoises. For migratory bird species, the PBR was compared to the total flyway population. Calculations and modelling were carried out to assess bird and bat collision risk, loss of habitat for birds and effects of underwater noise on porpoises. The outcomes were translated in permit conditions to be fulfilled within the new offshore wind farms. An example of the benefits of ongoing research for both project developers and biodiversity is shown by the permit conditions adapted to reduce bat collision risk. Due to new insights into the (estimated) numbers and behaviour of *Pipistrellus nathusii*, the migratory bat species that most commonly crosses the North Sea, a new set of permit conditions has been developed, based on multiple environmental parameters. Targeting certain conditions both reduces the loss of energy production from shut-down (by 12% for a modern wind turbine), while also significantly reducing the risk of mortality. These new permit conditions include:

- Period of the year: from 25 August to 10 October
- Time of the day: throughout the night, from sunset to sunrise
- Weather: consider wind direction, wind speed and temperature (see Table 3-1)

- Wind speed for starting wind turbine (cut-in speed): see Table 3-1 (combination of wind direction and temperature defines conditions for starting or stopping a wind turbine).

It should be stressed that the permit conditions for bats are based on limited data and professional judgement, including observations on bat activity under different environmental conditions, notably wind speed. However, as bat casualties at sea are rarely recorded, the effectiveness of this mitigation strategy cannot be directly monitored.

Table 3-1 Optimal standstill condition for new offshore wind turbines in The Netherlands

T(C)	N	NNO	NOO	O	ZOO	ZZO	Z	ZZW	ZWW	W	NWW	NNW
<11	3	3	3	3	3	3	3	3	3	3	3	3
11-15	3.5	4.5	5.5	6	5.5	5.5	3.5	3.5	3.5	3	3	3
15-17	3.5	4.5	5.5	6	5.5	5.5	4.0	3.5	3.5	3	3	3
17-19	3.5	4.5	5.5	6	5.5	5.5	4.0	3.5	3.5	3	3	3
>19	3.5	4.5	5.5	6	5.5	5.5	4.0	3.5	3.5	3	3	3

Source: https://www.noordzeeloket.nl/functies-gebruik/windenergie-zee/ecologie/cumulatie/kader-ecologie/ and for more concrete information on the research: Leopold *et al.*, 2014. A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea. IMARES Report C166/14 (https://www.researchgate.net/publication/296443757_A_first_approach_to_deal_with_cumulative_effects_on_birds_and_bats_of_offshore_wind_farms_and_other_human_activities_in_the_Southern_North_Sea)

3.5 Dealing with uncertainty in assessing and authorising wind energy development

During the appropriate assessment procedure and the preceding screening, authors often face a range of uncertainties. They can be distinguished as follows (Bodde *et al.*, 2018):

- inherent, i.e. it is not possible to know exactly;
- scientific, i.e. our current knowledge is incomplete or has a large confidence interval;
- social, i.e. there is no agreement on what information is relevant or required;
- legal, i.e. the information required to meet a legal standard is not known.

Overcoming uncertainty in each category typically requires applying more than one approach. In the context of an appropriate assessment it is typically the inherent and scientific uncertainty that leads to social and legal uncertainties. Finding solutions to inherent and/or scientific uncertainty is often imperative to efficiently navigating the assessment process (cCase study 3-3).

This is crucial in the context of decision-making, when it is for the competent national authorities, in the light of the conclusions of the appropriate assessment of the implications of a plan or project for the Natura 2000 site concerned, to approve the plan or project. They can only give their approval after they have made certain that the plan or project will not adversely affect the integrity of the site. That is the case where **no reasonable scientific doubt** remains that the plan will not lead to such effects. If doubt remains, the competent authority will have to reject authorisation. Furthermore, the authorisation criterion laid down in the second sentence of Article 6(3) of the Habitats Directive integrates the **precautionary principle** and makes it possible effectively to prevent the protected sites from suffering adverse effects on their integrity as the result of the plans or projects. A less stringent authorisation criterion could not as effectively ensure the fulfilment of the objective of site protection intended under that provision. **The onus is therefore on demonstrating the absence of adverse effects rather than their presence**, reflecting the precautionary principle. It follows that the appropriate assessment must be sufficiently detailed and reasoned to demonstrate the absence of adverse effects, in light of the best scientific knowledge in the field (European Commission, 2019, chapter 4.7.3).

Box 3-5 summarises typical issues of uncertainty in the wind energy development process. The most practical way of dealing with uncertainty in assessing significant effects is to identify the sources of uncertainty as early in the plan or project programme as possible. By engaging and consulting with the competent national authorities and key stakeholders (see Chapter 3.6), common ground can be found on how to acceptably manage these uncertainties.

Case study 3-3 Applying the precautionary principle in wind energy spatial planning - Capercaillie in the Black Forest (Germany) (LIFE project: LIFE98_NAT_D_005087)

Location: Black Forest, Germany.

Species: *Capercaillie Tetrao urogallus*

Challenge: Lack of knowledge on how wind energy development will threaten the species' population.

Solution: This lack of knowledge is compensated by making best use of the available knowledge about the species at risk. By systematically combining information on current distribution, long-term habitat potential and modelled species-specific dispersal patterns with ecological parameters from published literature (i.e. patch size, quality, accessibility, current use, function and connectivity), the study identified areas of different functionality and importance to meta-population persistence and connectivity. This information was fed into a spatial concept defining four area categories with different implications for wind-power development. It assigned the highest priority to areas covering the spatial and functional requirements of a minimum viable population, i.e. sites with the highest threat plausibility and the lowest uncertainty as regards importance for the population, and thus the strongest justification for precautionary measures.

The additional benefit of this approach is that it is neither too restrictive nor permissive.

This work yielded the following general recommendations for applying the precautionary principle in the field:

- Precautionary measures should focus on the relevant ecological unit, i.e. target viable populations and not local occurrences or individual animals;
- Measures should consider population dynamics processes, e.g. fluctuations in occupancy as well as population connectivity, instead of merely relying on a temporal snapshot of occurrence data;
- Measures should be based on a differentiated risk appraisal, with the estimated probability and severity of threat on the population and should result in gradated management implications or restrictions;
- The results must ensure at least the minimum requirements of a viable population are met, until further knowledge is available.

Since precautionary measures always represent an interim solution, it will be crucial to make regular revisions based on up-to-date knowledge. This also ensures that the precautionary principle is promoted as a valuable and justified basis for weighing ecological risks in conservation and landscape planning.

Source: Braunisch V. *et al.*, 2015.

Box 3-5 Examples of uncertainty in planning and permitting wind energy developments

- Plan or project location — there may be little or no prior knowledge of the ecological importance of the plan or project location; this is often the case at the level of spatial planning and in the absence of wildlife sensitivity maps.
- Project design trends — project design typically evolves from engineering feasibility (known as pre-front end engineering design) to construction, with screening and the assessment of significant effects taking place between the two stages of the design process.
- Baseline data — data may be incomplete or inexistent, resulting in a requirement to survey/sample a sufficiently large area (to monitor not only the site itself but also the surrounding landscape to identify functionally linked habitats e.g. roosting sites for bats) in order to provide key data such as estimates of species abundance/density.
- Predictive model parameters — there may be limited data on key variables such as bird flight heights, flight/swimming speeds, diurnal activity patterns, displacement thresholds, mortality rates and population responses to disturbance or mortality. There may also be limited data on landscape and weather conditions influencing a species' presence and risks (e.g. bats). Where data is limited, there is a need to rely on expert judgement and assumptions, which are inherently uncertain.
- For combined plans and projects, it is often uncertain which plans and projects may realistically contribute to cumulative effects (see Chapter 3.4 on Cumulative impact assessment). For example, it is typically the case that appropriate assessments for different projects vary in their data collection methods, analysis techniques and approach to managing uncertainty. It may then be difficult to quantitatively assess cumulative effects with any confidence.

A frequent application of the precautionary principle is to work with worst-case scenarios. However, caution is required. The Commission recognises that 'When the available data are inadequate or non-conclusive, a prudent and cautious approach to environmental protection, health or safety could be to opt for the worst-case hypothesis. When such hypotheses are accumulated, this will lead to an exaggeration of the real risk but gives a certain assurance that it will not be underestimated' (European Commission, 2000). The 'exaggeration of the real risk' as referred to by the Commission is due to the fact that, in many cases, the upper estimate of any uncertain component is systematically used to assess significance. For example, if modelling suggests that between five and ten marine mammals of a certain species may be subject to auditory injury (see Chapter 6.5) the assessment of significance would usually assume that ten animals are injured. Using the example of marine mammals and underwater noise again, worst-case assumptions are made for the noise level expected for pile driving[53], the duration of construction, the propagation of that noise underwater, the exposure of marine mammals and the predicted effects on animals. It is, however, ultimately for the competent national authority to take the responsibility and conclude if, in light of the evidence presented, it is certain that no reasonable scientific doubt remains as to the absence of an adverse effect on the integrity of the site.

Another type of uncertainty relates to the design characteristics of a project. When a national authority authorises a plan or project, it must have a complete understanding of the likely significant effects. If the national authority considers that the description of the plan or project contains sufficient uncertainty that the estimated level of significance of those effects is not beyond reasonable scientific doubt, they must require more detail or reject the application. The approach described in cCase study 3-4 illustrates one way to incorporate uncertainty in project design into the assessment of significant effects while providing the competent national authority with the certainty they need to assess the level of significance.

It is also good practice to establish early in the assessment process of a plan or project the expectations of what is acceptable and proportionate in relation to the application of the precautionary principle. To do this, it can be helpful to form an expert working group comprising of the competent national authority, national experts and other key stakeholders. The working group can make the best possible use of available scientific evidence, identify where there is likely to be uncertainty and agree on an approach that treats comparable situations evenly and avoids being too restrictive or permissive.

Appendix C provides an overview of good practice approaches to overcome typical uncertainties encountered in assessing wind energy developments.

Case study 3-4 The 'Rochdale Envelope': covering uncertainty in project design trends – Application to the Orsted offshore wind farm 'Hornsea 3'

The challenge

The UK has set a target to take a third of its energy from offshore wind by 2030. At the same time, it is aiming to reduce the cost of electricity to consumers. However, the current process from pre-application to construction can be lengthy and the technology available to developers is evolving rapidly. As a consequence, developers seek flexibility in their permitted designs to enable them to use the more cost-effective and efficient technology available at the point of construction, which may be some years after the consenting process commenced.

A solution

The design envelope, known as the 'Rochdale' approach to permitting allows developers to cater for emerging technologies in their consent applications and address to some degree the issue of uncertainty in design parameters (e.g. turbine specification, foundation type) during the application process. In this approach, consent is based on a range (or envelope) of potential designs. The use of a design envelope in planning was first tested in three English court cases [R. v Rochdale MBC ex parte Milne (No 1) and R. v Rochdale MBC ex parte Tew, 1999 and in R. v Rochdale MBC ex parte Milne (No 2), 2000] and hence is often referred to as a 'Rochdale Envelope' (Infrastructure Planning Commission, 2011).

The design envelope approach has been used in the majority of offshore wind farm applications in the UK. It is recognised that – given the complex nature of offshore wind farm development – many of the details of a proposed scheme may be unknown to the applicant at the time of the application, possibly including:

- the precise location and configuration of turbines and associated development;
- foundation type;
- exact turbine tip height;

[53] Pile driving or piling is the process of installing a pile into the ground without first excavating the area.

- cable type and cable route; and
- exact locations of offshore and/or onshore substations.

Practical/technical considerations
The key issue for a competent national authority to authorise a wind energy development project based on an envelope rather than a specific design relates to environmental impact. From an environmental impact perspective, the applicant must ensure that the EIA and the appropriate assessment undertaken has considered the worst-case design possible within the different options available in the design envelope. The worst-case scenarios vary by impact assessment type and can make the EIA and appropriate assessment process complex. It is particularly important that consultees during the consenting process understand the options considered and the implications in terms of assessing significant effects.

Advantages
The design envelope approach provides flexibility during the design and pre-planning phase of offshore wind energy projects and allows a degree of freedom to optimise wind turbine parameters prior to construction. It is a proven and acceptable approach to consenting where there is uncertainty in the final design of a project, and there is an established procedure for ensuring robust assessment of significant effects.

Case study: Orsted offshore wind farm 'Hornsea 3'
Orsted Power (UK) Ltd. (hereafter referred to as Orsted), on behalf of Orsted Hornsea Project Three (UK) Ltd., promotes the development of the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three). Hornsea Three will have a maximum of 300 turbines and a capacity of approximately 2.4 GW. The ultimate capacity of the project will be calculated based on available technology as set out in the design envelope. The environmental statement launching the EIA process defines the maximum design parameters for numerous technical parameters. An example is provided in the table below.

Parameter	Maximum design scenario – Most Numerous Turbine	Maximum design scenario – Largest Turbine
Number of turbines	300	160
Maximum height of lowest blade tip above LAT (m)	34.97	34.97
Maximum blade tip height above LAT (m)	250	325
Maximum rotor blade diameter (m)	195	265

At this early stage in the Hornsea Three development process, the project description is indicative and the 'envelope' has been designed to include sufficient flexibility to allow for further adjustments to the project during detailed design process, after consent. The environmental statement therefore sets out a series of options and parameters for which values are shown. To avoid excessive conservatism in the assessments, the parameters assessed throughout the Environmental Impact Assessments (EIAs) are not a combination of the maximum design parameters for each component. For example, the EIA has not assessed both the maximum number of turbines and the parameters related to the largest turbine type within the envelope, as this is not a feasible scenario. Instead, the maximum design scenario is chosen on a receptor-by-receptor and impact-by-impact basis, looking at a range of scenarios, whereby the physical size of the turbines is related to their number and the size of the associated infrastructure such as turbine foundations. These scenarios generally assume either the maximum number of turbines with the smallest turbine type, or the largest turbine parameters in the envelope with fewer turbines.

Source:
- Infrastructure Planning Commission (IPC), 2011.
- Hornsea Project Three Offshore Wind Farm — Environmental Statement: Chapter 3: Project Description (May 2018) https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-000528-HOW03_6.1.3_Volume%201%20-%20Ch%203%20-%20Project%20Description.pdf
- Rowe, J., *et al*, 2017.
- United States Department of the Interior Bureau of Ocean Energy. Management Office of Renewable Energy Programs. Draft Guidance Regarding the Use of a Project Design Envelope in a Construction and Operations Plan 12 January 2018 https://www.boem.gov/Draft-Design-Envelope-Guidance/

3.6 Public participation and stakeholder involvement

Public participation is legally embedded in the EIA and SEA procedure. Recent rulings issued by the Court of Justice of the EU have clarified that it also applies to the appropriate assessment procedure (see Box 3-6).

Box 3-6 Public participation in the Article 6(3) procedure under the Habitats Directive and in the EIA and the SEA Directive

Public participation in the Article 6(3) procedure.
According to the wording of Article 6(3), the opinion of the general public when authorising plans or projects requiring an appropriate assessment must be obtained only if it is considered 'appropriate'. However, the Court has clarified in a judgment on the basis of the requirements of the Aarhus Convention, to which all EU Member States are parties in their own right, that the public concerned, including recognised environmental NGOs, has the right to participate in the authorisation procedure. This right involves in particular, 'the right to participate 'effectively during the environmental decision-making' by submitting, 'in writing or, as appropriate, at a public hearing or inquiry with the applicant, any comments, information, analyses or opinions that it considers relevant to the proposed activity'' (C-243/15).

When the appropriate assessment is coordinated or runs jointly with an EIA/SEA, it can follow the provisions under those directives.

Public participation under the EIA Directive
Preamble of the Directive:

- *Effective public participation in the taking of decisions enables the public to express, and the decision-maker to take account of opinions and concerns which may be relevant to those decisions, thereby increasing the accountability and transparency of the decision-making process and contributing to public awareness of environmental issues and support for the decisions taken.*
- *Participation, including participation by associations, organisations and groups, in particular NGOs promoting environmental protection, should accordingly be fostered, including, inter alia, by promoting environmental education of the public.*
- *Among the objectives of the Aarhus Convention is the desire to guarantee rights of public participation in decision-making in environmental matters in order to contribute to the protection of the right to live in an environment which is adequate for personal health and well-being. Article 6 of the Aarhus Convention provides for public participation in decisions on activities not so listed which may have a significant effect on the environment.*

Article 6(2): *In order to ensure the effective participation of the public concerned in the decision-making procedures, the public shall be informed electronically and by public notices or by other appropriate means, of the following matters early in the environmental decision-making procedures referred to in Article 2(2) and, at the latest, as soon as information can reasonably be provided [see details in https://ec.europa.eu/environment/eia/eia-legalcontext.htm].*

Public participation under the SEA Directive
Preamble of the Directive:
In order to contribute to more transparent decision-making and with the aim of ensuring that the information supplied for the assessment is comprehensive and reliable, it is necessary to provide that authorities with relevant environmental responsibilities and the public are to be consulted during the assessment of plans and programmes, and that appropriate time frames are set, allowing sufficient time for consultations, including the expression of opinion.

Article 6(4): *Member States shall identify the public for the purposes of paragraph 2, including the public affected or likely to be affected by, or having an interest in, the decision-making subject to this Directive, including relevant NGOs, such as those promoting environmental protection and other organisations concerned.*

Legal compliance with the consultation steps set out in Box 3-6 must be based on good practice approaches in stakeholder engagement processes. An assessment that undertakes 'early and ongoing engagement with affected communities and interested stakeholders in a transparent, respectful, and accountable manner', reports on the outcomes of consultation and clearly identifies where actions have or have not been taken in relation to stakeholder concerns would be considered to meet international good practice (Brownlie & Treweek, 2018).

Consultations with experts, relevant authorities, NGOs, potentially affected groups or the general public can improve the environmental information available to those carrying out the appropriate assessment and to decision makers (e.g. by identifying environmental effects or designing suitable mitigation measures) and help minimise potential conflicts and delays.

Consultations with relevant authorities, biodiversity experts and stakeholders during the procedures laid down in Article 6(3) will enable information to be collected and ensure that all relevant data and expert opinions are available and taken into consideration. Nature conservation and sectoral authorities should cooperate during the assessment process to ensure that the appropriate assessment is based on the best available information and experiences and that all relevant aspects are properly taken into account.

Consultation might also take place at inter-sectoral level. Coordinated stakeholder consultation, in particular between wind/solar and grid developments, may lead to innovative practices, creative approaches and more flexibility to meet citizens' concerns and demands, as for example public acceptance for wind should be coupled with public acceptance for grids.

Box 3-7 summarises the key principles of effective stakeholder consultation and engagement.

Box 3-7 Guidance on effective stakeholder consultation and engagement (adapted from European Commission, 2018b)

Timing of stakeholder participation. Stakeholder involvement should start in the earliest stages of wind energy development planning so that relevant environmental information can be used when considering location alternatives. Wildlife sensitivity mapping complemented with up-to-date information from local experts and other stakeholders is the best way to take informed decisions on siting. Stakeholder consultation should continue throughout the subsequent stages of planning and permitting. Overall, early consultation with stakeholders will improve the environmental information supplied to decision makers, minimise misunderstandings that can lead to potential conflicts and delays and lead to more widely accepted projects with a greater sense of local ownership (European Commission, 2018b).

Identifying relevant interest groups. Identifying the relevant interest groups or stakeholders is critical to successful public involvement, be it in a policy, plan, programme (e.g. sectoral or regional) or project. Relevant stakeholders in the context of planning and permitting wind energy developments are:

- authorities in charge of spatial planning, renewable energy policy, nature conservation, landscape conservation;
- experts, in particular local experts and NGOs with expertise in local biodiversity values, but also experts in biodiversity impact assessment, in particular with regard to wind energy (consultants, academia);
- the wind energy sector: the sector itself has the practical expertise and experience with building and operating wind farms and often has acquired very relevant insights in the effectiveness of mitigation measures;
- the general public.

At national or regional scale, it is a useful approach to create multi-stakeholder cooperation platforms with the government, the wind energy sector and NGOs as key partners, with the aim of collecting and exchanging information with the ultimate goal to develop protocols. This is the practice in Germany and France (see cCase study 3-5 and cCase study 3-6).

Choosing the right form of communication and consultation. Public involvement can range from simple dissemination of information to consultation and full participation in decision-making:

- Informing: one-way flow of information from the proponent to the public;
- Consulting: two-way flow of information between the proponent and the public, giving the public an opportunity to express their views and the proponent to respond;
- Participating: two-way flow of information and ideas in which the proponent and the public are involved in shared analysis and agenda-setting and the public/stakeholders are voluntarily involved in taking decisions on project design and management through consensus on the main points.

Obviously participatory planning is the most recommended approach as it is the only meaningful form of stakeholder engagement. Moreover, the entire process needs to be transparent and open, the language must be easy to understand and the data should be made open to the public when requested.

The following two case studies describe well-established national multi-stakeholder cooperation structures related to wind energy in Germany and France. In other countries, specific research programmes are created related to wind energy and biodiversity, e.g. in Sweden[54], Belgium[55], and The Netherlands[56].

Case study 3-5 Multi-stakeholder cooperation in Germany

In Germany, there are good examples of stakeholder cooperation at national level, both for offshore and onshore wind energy developments.

The following good procedures set up at national level are run for the purpose of integrating biodiversity considerations in the planning and permitting of wind farms:

- Setting a combination of five high-quality criteria (thresholds) with regard to the significance of effects of wind energy on biodiversity;
- Organising and coordinating research and monitoring, in particular with regard to birds and bats, mainly for offshore wind energy developments.
- Developing and providing advice on methodologies for both the private and public sector to assess and reduce the impact on bats, birds and marine mammals.
- Organising conferences and workshops and participating in international events, especially by the nature conservation agencies and RES associations.

Offshore

The Federal Maritime and Hydrographic Agency (*Bundesamt für Seeschifffahrt und Hydrographie*, BSH) is an important maritime service provider in Germany that performs a wide range of services, including environmental protection, monitoring the marine environment, and maritime spatial planning in the German Exclusive Economic Zone (EEZ). It is in charge of approving permit applications for marine wind farms and pipelines.

The BSH has issued several standards for environmental investigations of marine mammals as well as technical and construction requirements. These standards were developed by representatives of federal agencies, the offshore wind industry, consultancies, NGOs and research institutes. It has published the following standards[57]: Standard Investigation of the impacts of offshore wind turbines on the marine environment (StUK 4), separated in:

- Measuring instructions for underwater noise monitoring
- Offshore wind parks — predictions for underwater noise, minimum requirements on documentation
- Measuring specification for the quantitative determination of the effectiveness of noise control systems
- Study to evaluate the calibration of C-POD devices used to detect marine mammal vocalisations (only in German)
- Investigation of benthos, biotope structure and biotope types in the context of application processes for cable trays for the connection of offshore wind farms (only in German)
- Standard design: minimum requirements concerning the construction design of offshore structures within the EEZ.

There is a standard procedure for the baseline monitoring of the marine environment (prior to approval of a project) and for the mandatory monitoring during the construction and operation of a wind farm. Baseline studies must be conducted for two years before construction of the development. If over five years have passed between the end of the baseline studies and the start of construction, another full two-year baseline survey must be carried out.

Onshore

Regarding onshore wind energy developments in Germany, the non-profit association FachAgentur Windenergie (FA Windenergie) is set up, consisting of the federal government, the states, the municipalities, business and nature conservation associations, as well as companies. FA Windenergie brings together a large number of stakeholders and assists them in coping with challenges nationwide through extensive information, research and knowledge transfers.

For example, FA Windenergie has published an overview of good practices of wind energy developments in forests. For the Windpark Lauterstein, Göppingen, a cooperative approach involving all stakeholders resulted in positive experiences for planning and implementation, such as relocating storage areas outside the forest to reduce the area cleared.

Source: https://www.bsh.de/DE/PUBLIKATIONEN/_Anlagen/Downloads/Offshore/Standards/Standard-Investigation-impacts-offshore-wind-turbines-marine-environment_en.pdf?__blob=publicationFile&v=6https://www.fachagentur-windenergie.de/

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[54] http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Research/Vindval--a-programme-of-knowledge/
[55] https://odnature.naturalsciences.be/mumm/en/windfarms/
[56] https://www.noordzeeloket.nl/functies-gebruik/windenergie-zee/ecologie/
[57] https://www.bsh.de/EN/PUBLICATIONS/Offshore/offshore_node.html

https://www.fachagentur-windenergie.de/fileadmin/files/Veroeffentlichungen/FA_Wind_Good_Practice_Wind_im_Wald_12-2017.pdf

Case study 3-6 Multi-stakeholder cooperation in France

The national programme on wind energy and biodiversity (‘*Programme éolienne et biodiversité*’) is a very good example of stakeholder cooperation at national level. The programme partners were the French Ministry, Birdlife (its local organisation LPO — *Ligue pour la Protection des Oiseaux*) and the private sector. The LPO was responsible for technical coordination and the programme was supervised by a steering group involving all partners.

The programme aims to promote the integration of biodiversity considerations in the planning and permitting of wind farms, both onshore and offshore. For this purpose, a number of measures were taken at both national and local level, such as:

- Setting high-quality criteria (thresholds) to assess the effects of wind energy on biodiversity, in particular birds and bats;
- Structural evaluation of effects by establishing a permanent national observatory centre for assessing effects on birds and bats;
- Organisation and coordination of research (see link below) and monitoring in particular with regard to birds and bats;
- Developing and advising on methodologies for the private and public sector and maintaining technical library related to the issue;
- Organising conferences and workshops and participating in international events;
- Preparing and providing information, either general or technical, to interested stakeholders, including the general public.

The French authorities encourage meetings between stakeholders at an early stage, even before the project‘s permit application is submitted. The French regulation allows early communication with stakeholders and allows files to be blocked at a very early stage (to avoid spending time and money on applications that have no prospects). These early steps are not to be confused with the public consultation process required under the authorisation process, once the permit application is submitted to the authorities.

Source:
https://eolien-biodiversite.com/programme-eolien-biodiversite/
https://eolien-biodiversite.com/comment-les-eviter/etudes-r-d/

4. STRATEGIC PLANNING

4.1 General information

4.1.1 Strategic planning in the general context of wind energy

In order to reconcile wildlife interests with the need to expand renewable energy, it is necessary to plan new infrastructure in a strategic manner over a large geographical area. Strategic planning will also be a good basis for assessing applications for permits within the timeframes specified in the revised Renewable Energy Directive (EU) 2018/2001 i.e. two years for new power plants and one year for repowering.

Under the Regulation 2018/1999[58], Member States must draw up national energy and climate plans (NECP) to achieve their planned contributions to the EU's 2030 renewable energy target. Furthermore, under Article 15(7) of the revised Renewable Energy Directive (2018/2001), Member States must carry out an assessment of potential renewable energy sources and 'where appropriate, include spatial analysis of areas suitable for low-ecological-risk deployment'. Therefore, the NECPs should form the basis for spatial plans at national and/or regional scales or at least inform these. The spatial plan may include all renewable energy types, or it may focus on individual sectors such as wind energy development. The plans should be subject to SEA for identifying and assessing effects (including cumulative effects) while highlighting knowledge gaps and research needs as well as potential alternative delivery options that avoid or minimise likely significant effects.

Strategic planning in this context involves a decision-making process. This must first of all determine whether and to what extent wind energy development is indeed the most environmentally, geographically, socially and economically suitable mechanism to meet the carbon emission reduction and renewable energy targets. Secondly, it must carry out spatial planning of wind energy developments. Although wind energy is considered as a key renewable energy source with high growth potential in the EU, regional circumstances may well favour other technologies or emission-reduction strategies. Spatial planning encompasses a wide range of physical, socio-economic and environmental conditions and requirements in order to identify the locations that are best fit for purpose. Strategic planning of wind energy developments takes into account not only wind conditions, but also the technical feasibility for construction (e.g. sea depth, accessibility of mountain ridges), connection to electricity grid, distance to human settlements, landscape, nature conservation objectives, etc. All these conditions need to be considered and can affect the feasibility and implementation of wind energy projects. In this guidance document the focus is on nature conservation.

Box 4-1 Elements in defining technical wind energy development and wildlife sensitivity

Technical and socio-economic considerations for suitable wind energy development locations:

- wind resource conditions (e.g. speed, turbulence, extreme wind speeds, wind shear, flow condition)
- access to and capacity of the electrical transmission and transport networks
- ground/seabed conditions and topography
- proximity to residential areas
- land/seabed availability and existing land/sea uses
- proximity to existing aviation (tip height restrictions) and shipping navigation corridors
- restrictive noise regulations
- safeguarding distances to radar or airports

Wildlife sensitivity

- Natura 2000 site location, location of functionally linked land (e.g. areas outside Natura 2000 sites that are important for foraging by species for which the Natura 2000 site is designated) including the flyways/migration routes between Natura 2000 sites.
- Other national/regional protected areas and other areas/habitats that are (potentially) important for protected species[59].

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[58] https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ%3AL%3A2018%3A328%3ATOC&uri=uriserv%3AOJ.L_.2018.328.01.0001.01.ENG

[59] Although this guidance focuses on Natura 2000 sites, wildlife sensitivity mapping is a broader tool, not restricted to sites.

- The distribution[60] of EU-protected habitats and species, with particular focus on wind energy-sensitive species, such as bats[61], birds[62] and sea mammals.
- The conservation status[63] of the natural habitats and/or the populations of the protected species and, if EU-level wildlife sensitivity maps are used, also the conservation status at EU-level.

Spatial planning of wind energy developments needs to be subject to SEA and – unless screening excluded the likelihood of significant effects on any Natura 2000 sites – also to an appropriate assessment. SEA is also a good framework to use to address cumulative effects. Permitting wind-farm developments for which the siting has been underpinned by solid strategic planning with careful and early consideration of biodiversity will be much smoother than if biodiversity concerns in wind-farm projects are only addressed later in the process.

The assessment of a spatial plan does not remove the need for an assessment of projects arising from the plan. A spatial plan should ideally identify categories of locations suitable for wind energy development, listed in order of priority ranging from locations of low-ecological-risk deployment (in terms of the objectives of the Nature Directives) to locations of high-ecological-risk deployment. In sites with exceptionally high biodiversity values, this could even lead to defining exclusion zones. The spatial plan provides for early discussions with project promoters to ensure that an envisaged project includes solutions to address all the identified sensitive issues, especially if the project is located in a high-ecological-risk deployment area. The assessment of spatial plans related to wind energy should also guide the assessment of projects arising from the plan by identifying key knowledge gaps and the likely suite of measures needed to avoid or reduce significant adverse effects. It is imperative therefore that the assessment of the spatial plan is supported by baseline data appropriate to the scale of the spatial plan. Details of the assessment of the spatial plan, including baseline data, should be made available to developers and other stakeholders to facilitate the assessment of projects.

4.1.2 Strategic planning for offshore wind energy

Two directives are of particular importance to the deployment of low-ecological-risk offshore wind energy developments: Directive 2014/89/EU on establishing a framework for maritime spatial planning (the Maritime Spatial Planning Directive) and Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (the Marine Strategy Framework Directive). The Maritime Spatial Planning Directive aims to promote the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The importance of maritime spatial planning is also acknowledged by the North Sea Energy Forum[64] and the Baltic Energy Market Interconnection Plan[65].

Spatial planning approaches should adopt an ecosystem-based approach[66] [67] with Member State's spatial plans contributing to the sustainable development of the energy sector at sea, maritime transport, fisheries and aquaculture, and the preservation, protection and improvement of the environment. At a regional sea level,

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[60] The distribution is often not well known (e.g. bats). Potential habitats (for example model results) can also be included for wildlife sensitivity mapping.
[61] Bats live in a network of functional habitats and migrate on a daily basis between (maternity and summer) roosts and feeding habitats, and on a seasonal basis between regions where maternity takes place and where hibernation takes place.
[62] See for instance the 'Helgoland Paper' by the inter-regional working group of regional state offices for bird conservation in Germany that recommends minimum distances between occurrences of relevant birds and windmills (http://www.vogelschutzwarten.de/downloads/lagvsw2015.pdf).
[63] See Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC (https://ec.europa.eu/environment/nature/conservation/species/guidance/pdf/guidance_en.pdf).
[64] See Political Declaration on energy cooperation between the North Seas Countries — Support Group 1 on Maritime Spatial Planning; https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1138
[65] See EU Strategy for the Baltic Sea region https://ec.europa.eu/regional_policy/sources/docoffic/official/communic/baltic/action_20032017_en.pdf
[66] See Policy Brief 'Implementing the Ecosystem-Based Approach in Maritime Spatial Planning' (Version: 25 October 2018); https://www.msp-platform.eu/sites/default/files/20181025_ebainmsp_policybrief_mspplatform.pdf
[67] See HELCOM Guideline for the implementation of ecosystem-based approach in Maritime Spatial Planning (MSP) in the Baltic Sea area; http://www.helcom.fi/Documents/Action%20areas/Maritime%20spatial%20planning/Guideline%20for%20the%20implementation%20of%20ecosystem-based%20approach%20in%20MSP%20in%20the%20Baltic%20Sea%20area_June%202016.pdf

it is most recommended that Member States cooperate with each other on spatial planning and on assessing and monitoring the (cumulative) effects of offshore wind farms.

Member States were required to transpose the directive in their national legislation and designate the relevant authorities by 18 September 2016. They were to draw up maritime spatial plans for their marine waters by 31 March 2021. The European Commission produced an information document for stakeholders and planners examining the Maritime Spatial Planning Directive in relation to the energy sectors in 2015. A step-by-step guide to maritime spatial planning was published by Ehler & Douvere (2009) with the online 'European MSP Platform'[68] providing an information and communication gateway designed to offer support to all EU Member States in their work to implement marine spatial planning. The EU provided guidance on cross-border cooperation in maritime spatial planning (Carneiro, 2017)[69]. One of the objectives of the MSP Platform is to provide guidance to resolve potential conflicts between sectors. For instance, it proposes a number of solutions to mitigate the 'wind energy – conservation' conflict, one being to use GIS-based sensitivity mapping to avoid essential habitats and another being to establish multi-use marine protected areas and offshore wind.

The spatial needs of offshore wind energy developments include the turbines, the cable connections between turbines, converter stations, substations and the export transmission cable to the onshore electricity network. As a result of the connection between offshore infrastructure and onshore infrastructure, it is essential that maritime spatial planning takes account of land-sea interactions. The European Commission has also provided guidance on land-sea interactions in maritime spatial planning (2018)[70].

The main goal of the Marine Strategy Framework Directive is to achieve good environmental status of EU marine waters by 2020. Article 3 of the Directive defines good environmental status (GES) as 'the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive'. GES means that the different uses made of the marine resources are conducted at a sustainable level, ensuring their continuity for future generations. In addition, GES means that:

- ecosystems and their hydro-morphological (i.e. the structure and state of water resources), physical and chemical conditions are fully functioning and resilient to human-induced environmental change;
- the decline of biodiversity caused by human activities is prevented and biodiversity is protected;
- human activities that put substances and energy into the marine environment do not cause pollution effects. Noise from human activities is compatible with the marine environment and its ecosystems.

To help Member States interpret what GES means in practice, the Directive sets out, in Annex I, 11 qualitative descriptors that describe what the environment will look like when GES has been achieved. In particular, the following GES descriptors relevant to offshore wind energy developments and the EU nature legislation are covered in this guidance:

- Descriptor 1. Biodiversity is maintained.
- Descriptor 6. The sea floor integrity ensures functioning of the ecosystem.
- Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem.
- Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem.

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[68] https://www.msp-platform.eu/msp-eu/introduction-msp
[69] https://op.europa.eu/en/publication-detail/-/publication/985c28bb-45ab-11e7-aea8-01aa75ed71a1
[70] Work on maritime spatial planning under the regional cooperation for the North Sea and the Baltic (North Seas Energy Forum (https://ec.europa.eu/energy/en/events/north-seas-energy-forum) and BEMIP (https://ec.europa.eu/energy/en/topics/infrastructure/high-level-groups/baltic-energy-market-interconnection-plan) is also relevant.

4.2 Using wildlife sensitivity mapping for strategic planning of wind energy

4.2.1 Introduction

Wildlife sensitivity maps are recognised as an effective tool for identifying areas where the development of renewable energy might affect sensitive communities of wild plants and animals, and thus should be avoided. They can be used to identify at an early stage in the planning process areas containing ecological communities sensitive to wind energy developments.

The Commission has supported the development of a Wildlife Sensitivity Mapping Manual, a practical tool for developing wildlife sensitivity maps for renewable energy in the EU (see Appendix D). This manual presents a comprehensive overview of the datasets, methodologies and GIS applications needed to develop effective (WSM) approaches within an EU context. It focuses on species and habitats protected by the EU Nature Directives, with particular emphasis on birds, bats and marine mammals.

Wildlife sensitivity maps typically inform strategic planning decisions during the initial site selection phase of the development process and therefore are intended to operate at a landscape scale, often with regional, national or multi-national coverage. As such, wildlife sensitivity mapping approaches do not replace the need for site-specific Appropriate Assessment under Art.6(3) of the Habitats Directive and Environmental Impact Assessments (EIAs). They can, however, also be used during EIAs and post-consent to inform micro-siting and possible management prescriptions.

Wildlife sensitivity maps use geographic information systems (GIS) to collate, analyse and display spatial and geographic data. They use spatial biodiversity data on species and/or sites. They typically use existing biodiversity datasets, but sometimes data are collected explicitly to aid the creation of a wildlife sensitivity map. Most approaches do more than simply displaying spatial datasets – site boundaries, species ranges and records, geographic features – they also assign sensitivity values derived from the data. They are predictive, providing a forecast of potential sensitivity at one or more sites, or across a wider landscape, based on the best available data and on mathematical and graphical modelling.

However, some limitations of wildlife sensitivity mapping need to be borne in mind. First, it should not be used as an instrument to indicate suitable alternative sites, as this also depends on several other constraints and conditions. Secondly, certain taxa will inevitably prove more difficult to assess with limited data on their distribution and incomplete knowledge on how they are affected. For these groups, a more rudimentary analysis and a more precautionary interpretation will be needed.

4.2.2 Examples of wildlife sensitivity mapping approaches for onshore and offshore wind energy developments

Wildlife sensitivity mapping (WSM) is most commonly associated with wind energy and the vast majority of approaches have involved mapping bird communities regarded as sensitive to the operation of wind farms (on- and offshore). For other species such as bats, WSM is more difficult to use effectively, but it can be used as part of a suite of tools to assist in strategic planning where the underpinning data exists.

This chapter highlights some best practice applications of WSM in the field of onshore and offshore wind energy. More information about these case studies can be found in the Wildlife Sensitivity Mapping Manual.

Case study 4-1 presents the wind energy sensitivity map for birds and bats in Flanders (Belgium), one of the few combined WSM approaches for birds and bats. Case study 4-2 focuses on the soaring bird sensitivity map for wind energy development in Thrace (Greece). Case study 4-3 presents SeaMaST, a tool that maps the sensitivity of seabirds and inshore water birds to offshore wind farms in English territorial waters.

Case study 4-1 Wind farm sensitivity map for birds and bats in Flanders (Belgium)

The wind farm sensitivity map for birds and bats in Flanders aims to indicate areas where siting wind turbines may pose a risk to birds or bats. It is intended to inform and guide more site-level assessments and strategic planning. It is an example of a multi-species sensitivity map and demonstrates how dissimilar groups can be assessed in a single tool.

It classifies the region into four categories of high, medium and possible risk, as well as low risk/no data. The sensitivity maps and accompanying guidelines are frequently used in siting decisions in Flanders. Project developers and consultancies use them for strategic planning and as 'starting point' for more detailed site-level project assessments. Local and regional authorities apply them for the same purpose and for checking if project developers and consultancies did their job well. It must be emphasised that for high-risk areas, local assessment should be more detailed. Although aspects of the map are distinctive to Flanders, the principles could be readily applied elsewhere.

Sensitivity map for birds

The instrument includes a GIS-based vulnerability map for birds, which is made up of nine thematic maps (e.g. foraging and resting areas for non-breeding wildfowl, seasonal migration routes) and a habitat prediction map. These layers are best examined individually but can also be overlaid to give an overview of all potential sensitivities. The stacked layers (as synthesis map) are shown below with sensitivity categories represented as high (3), medium (2) and possible risk (1), as well as low risk/no data (0). This map can be consulted in detail within a web-based application that also provides other important maps (like protected nature reserves, Natura 2000 areas, etc.).

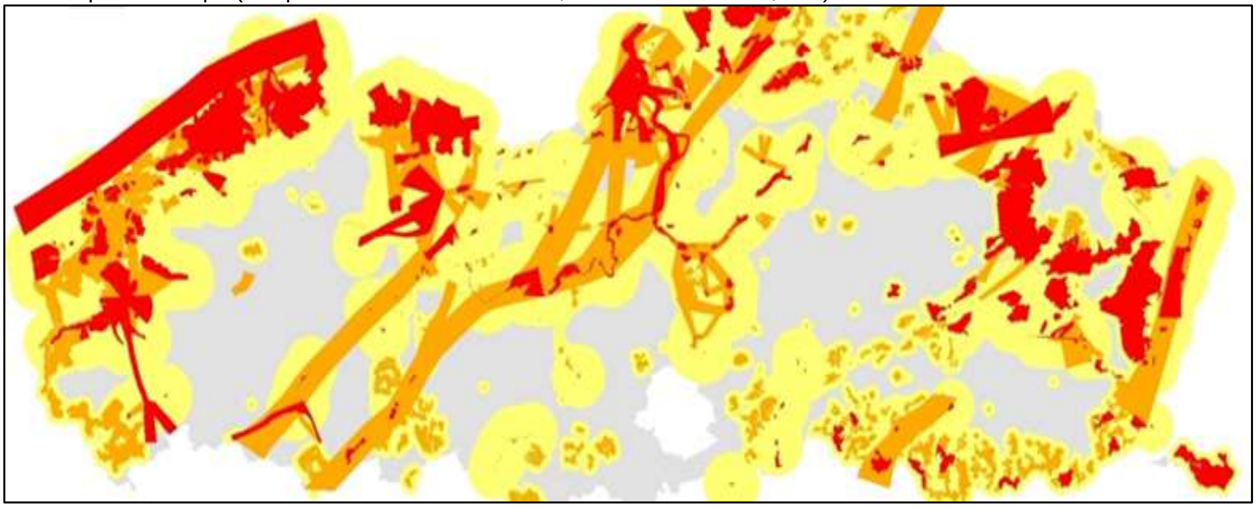

Figure 4-1 Synthesis map of bird sensitivity to wind turbines in Flanders (red: high risk; orange: medium risk; yellow: possible risk; grey: not sufficient information)

Sensitivity map for bats

The sensitivity map for bats (see Figure 4-2) differs from the previous thematic maps for birds. It is based on the identification of a suitable habitat (using aerial photographs and land cover field inventory), which was used as a predictor of bat presence.

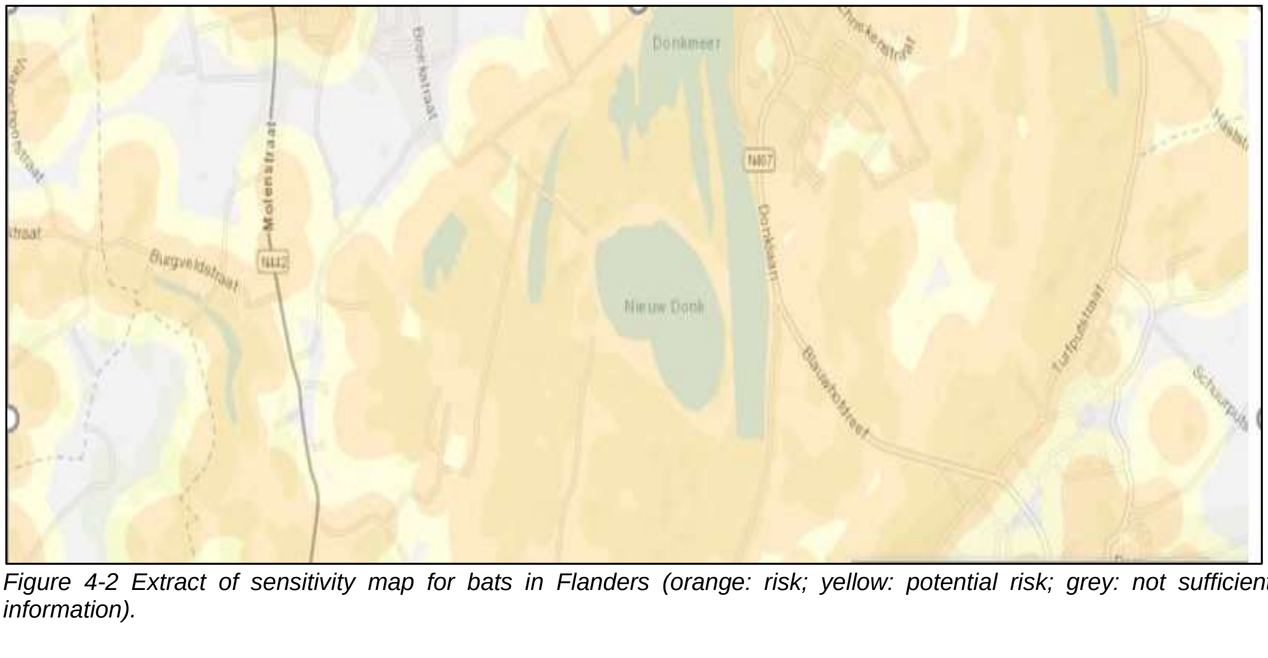

Figure 4-2 Extract of sensitivity map for bats in Flanders (orange: risk; yellow: potential risk; grey: not sufficient information).

There are two main caveats to using this type of mapping for bats. Firstly, habitat suitability models are much more accurate for species that are habitat specialists (these tend to be Annex II species that are at lower risk from wind developments). Higher-risk species tend not to be habitat specialists, and are therefore both more widespread and common, and found even in habitats that would be considered sub-optimal for bats. For example, in the UK, a high proportion of common and soprano pipistrelle casualties are found in locations that would not be classified as particularly valuable to bats (e.g. uplands without trees and hedgerows), but suitable for wind developments. Secondly, although the habitat predictions are combined with data such as roost locations to generate areas of differential risk, in practice data is lacking in all Member States.

Source: https://geo.inbo.be/windturbines/
Background information and guidance in the report (in Dutch):
Everaert J. (2015). *Effecten van windturbines op vogels en vleermuizen in Vlaanderen. Leidraad voor risicoanalyse en monitoring. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2015* (INBO.R.2015.6498022). Instituut voor Natuur- en Bosonderzoek, Brussels.
Summary (in English) in the presentation: Everaert (2018). Wind farm sensitivity map for birds and bats in Flanders (Belgium). Presentation at workshop to prepare an instructional toolkit outlining the development and implementation of Wildlife Sensitivity Mapping to inform renewable energy deployment in the EU, 22/10/2018, Brussels, Belgium. https://pureportal.inbo.be/portal/files/16505980/sensitivitymaps_Joris_Everaert_voorpdf.pptx

Case study 4-2 Soaring bird sensitivity map for wind energy development in Thrace (Greece)

The region of Thrace is of exceptional ornithological importance as it hosts habitats that are of European-wide significance, mainly for large birds of prey and aquatic birds. A large part of the region has been selected as priority area for the development of wind energy, as it is also one of the areas with the highest wind capacity in mainland Greece. Specifically, most of the regional unit of Evros and part of the unit of Rodopi have been identified as Wind Priority Area 1 (WPA 1) under the National Renewable Energy Spatial Plan framework. WPA 1 covers about half of the region's Natura 2000 sites, including the two national parks, and overlaps with the area used by the birds of prey in the region. Half of WPA 1 (53%) falls within the core area of the Cinereous Vulture (*Aegypius monachus*) population and also envelops the strictly protected area of Dadia National Park.

In an effort to determine the conditions that can lead to the sustainable development of wind farms in Thrace, WWF Greece drew up a proposal for selecting the site of wind farms in WPA 1 (WWF Greece 2008).The proposal includes a soaring bird sensitivity map that provides authorities, investors and other stakeholders with the information required to take well-informed decisions. The map divides the region into two distinct categories based on the distribution of highly vulnerable bird species: 'exclusion zones' and 'increased protection zones'. Exclusion zones are locations where wind farm installation should be excluded. By contrast, increased protection zones are locations where wind farms could be installed with appropriate mitigation in place. The overall site selection overlaid areas of sensitivity for colonies of cinereous vultures and griffon vultures, with the territories of and black storks and with national parks.

A sensitivity map for the cinereous vulture population was prepared, based on a conservation priority system of nine zones (see Figure 4-3). This includes a core area of vital importance (70% of time spent by individuals on average), a non-core area and a periphery (less than 5% of time spent). The core and non-core areas are further prioritised into four conservation zones each, according to the population fraction that used each zone (1: <25%, 2: <50%, 3: <75%, 4: >75%) on the basis of a home-range analysis of 19 tagged individuals.

This range-use modelling was combined with a collision risk model to predict the cumulative collision mortality for cinereous vulture under all operating and proposed wind farms. The model gave four different vulture avoidance rates.

On the basis of a sensitivity map, a spatially explicit solution was created to meet the national target of wind harnessing at a minimum conservation cost of less than 1% population loss, providing that population mortality (5.2%) caused by the operating wind farms in the core area would be fully mitigated. Under other scenarios, the vulture population would probably be at serious risk of extinction.

The findings emphasised the need to officially designate the population core area as a **wind farm exclusion zone**, since it is the most vital area for the survival of the population. It was also found to account for almost all cumulative collision mortality for cinereous vulture, and for being important to other species prone to collision.

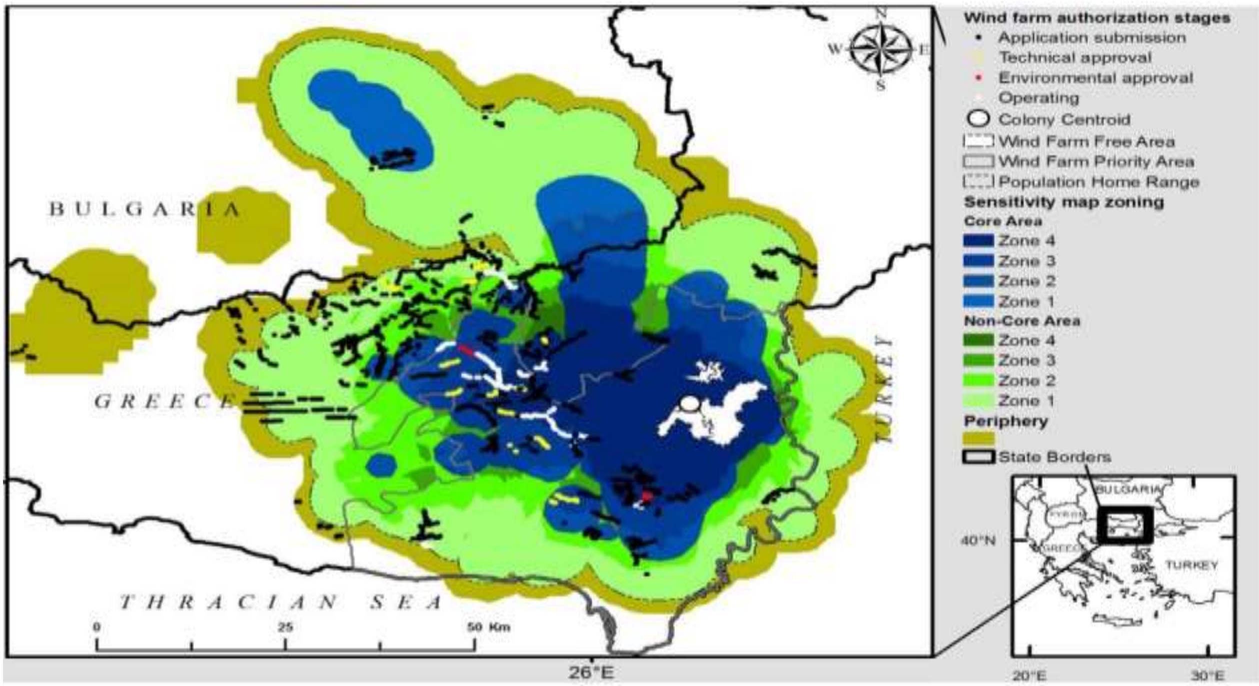

Figure 4-3 Wind farms at different authorisation stages within a sensitivity map for cinereous vulture. Large numbers of wind farms are concentrated in areas of vital conservation importance (70% of time spent by individuals on average), as indicated by the nine zone sensitivity map for Cinereous vulture (Aegypius monachus) (from Vasilakis et al. 2016).

Although the sensitivity map has not been adopted formally, the map is being used by both developers and competent authorities during the design and assessment phase of wind farm projects in Thrace. Despite its lack of legal status, it is regarded as providing the soundest scientific basis for planning.

Source:

- Vasilakis D, Whitfield P., Schindler S., Poirazidis K & Kati V., 2016. Reconciling endangered species conservation with windfarm development: Cinereous vultures (*Aegypius monachus*) in south-eastern Europe; Biological Conservation 196 (2016) 10-17.
- Vasilakis D, Whitfield P, Kati V., 2017. A balanced solution to the cumulative threat of industrialised wind farm development on cinereous vultures (*Aegypius monachus*) in south-eastern Europe. PLoS ONE 12(2): e0172685.doi:10.1371/ journal.pone.0172685.

Case study 4-3 SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm effects in English territorial waters

The geographic information system tool, SeaMaST (Seabird Mapping and Sensitivity Tool) was created to provide evidence of the use of sea areas by seabirds and inshore water birds in English territorial waters, mapping their relative sensitivity to offshore wind farms.
It uses high-quality seabird survey data gathered during surveys at sea of two main seabirds databases, namely from the European Seabirds at Sea (ESAS) boat-based survey and the WWT Consulting aerial-based survey datasets. It currently contains information on 53 species for the following families: *Anatidae* (ducks), *Gaviidae* (divers), *Podicipedidae* (grebes), *Procellariidae* (fulmars), *Hydrobatidae* (storm petrels), *Sulidae* (gannets), *Phalacrocoracidae* (cormorants), *Scolopacidae* (sandpipers), *Stercorariidae* (skuas), *Laridae* (gulls), *Sternidae* (terns) and *Alcidae* (auks). A density surface model was produced to map the density of these seabirds in English waters out to 200 nautical miles or to the neighbouring territorial waters boundary.

Sensitivity scores were generated based on four factors representing conservation importance (factors a to d), and on six aspects of species behaviour called ‘species vulnerability factors’ (e to j): status in relation to the Birds Directive (a), percentage of the biogeographic population that occurs in England/ English waters during any particular season (b), adult survival rate (c), UK threat status (d), flight altitude (e), flight manoeuvrability (f), percentage of time flying (g), nocturnal flight activity (h), disturbance by wind farm structures, ship and helicopter traffic (i), and habitat specialisation (j).

Sensitivity mapping scores were applied to the density factor of each species in each 3km x 3km grid cell to generate separate and combined sensitivity maps for collision and displacement.

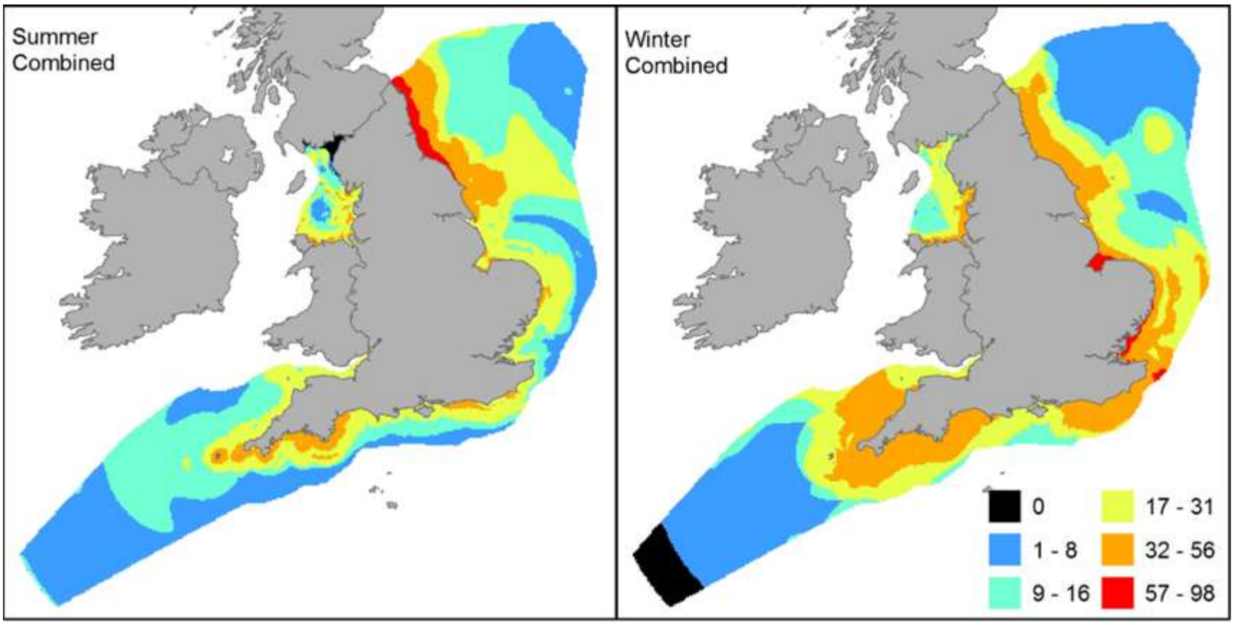

Figure 4-4 Examples of wind farm sensitivity maps from SeaMaST

The SeaMaST tool is based on a combination of high-quality data and proven methods. It has resulted in a high-quality sensitivity map for seabirds in English territorial waters. The methods could be extended to include other regions and/or could be applied elsewhere.

The tool is a freely available as a GIS resource intended for use by the offshore wind industry and marine spatial planners. To date, it has been promoted for use in informing wind farm development and marine spatial planning. Although the map has not formally been integrated within the planning process, it is regularly used by authorities, NGOs etc.

Source: http://bit.ly/2xON74V

4.3 Multiple use of wind energy development sites

Combining land use in wind energy development sites with other economic activities (e.g. other renewable energy sources, aquaculture), or even with nature conservation or restoration projects, is an excellent way to implement spatial planning. The aim is to minimise the adverse effects of wind energy on biodiversity and, in an increasing number of cases, even to enhance biodiversity in these sites.

Europe already has examples of sites that co-locate wind energy developments with other renewable energy systems as a means of smoothing out electricity generation (Natural Power, 2018). An example is the Schneebergerhof co-located solar and wind farm (see Figure 4-5). Although technical and economic conditions can limit the commercial use of utility-scale battery-storage technology (WindEurope, 2017b), removing these barriers is likely to facilitate further plans for co-located developments. Battery-storage technology has a number of benefits, including a more consistent means of balancing energy supply and demand.

Figure 4-5 Schneebergerhof co-located wind energy development, Germany[71]

Onshore wind energy developments are typically co-located with other land uses such as agriculture and, increasingly, forestry (Richarz, 2014; Helldin, 2017). Emerging co-location opportunities in the marine environment are also being investigated in several Member States, with a particular focus on assessing the commercial feasibility of offshore shellfish culture (Buck *et al.*, 2017; Syvret *et al.*, 2013).

Case study 4-4 and Case study 4-5 provide specific examples of multiple-use applications of offshore wind energy developments. Another example is the concept of energy islands, which not only provide opportunities for wind and other renewable energy developments but also for the creation of habitats, aquaculture etc. An example is the North Sea Wind Windpower Hub[72], a plan developed by a consortium of energy companies (Gasunie, Tennet, Energinet) and the Port of Rotterdam.

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[71] Source: © Armin Kübelbeck. (CC BY-SA 3.0) https://commons.wikimedia.org/wiki/File:Schneebergerhof_01.jpg Wind Park Schneebergerhof: https://www.juwi.com.au/wind-energy/references/detail/artikelansicht/wind-park-schneebergerhof/
[72] https://northseawindpowerhub.eu/

Case study 4-4: The Edulis project, an example of combined wind energy generation and aquaculture in the North Sea (Belgium)

Increased sea activities along the coast, growing consumer demand for sustainable and local food production and technological improvements are pushing aquaculture activities to move offshore, both across the EU and worldwide. The co-location of offshore wind farms with aquaculture could secure renewable energy generation while increasing food security, employment and local production. Pilot studies in the North Sea have demonstrated that the biological and chemical conditions along the Belgian North Sea coast are highly suitable for growing mussels. The Edulis project (2016 – 2018) is a world-leading example of aquaculture located within offshore wind farms in a climatically harsh environment. The project has assessed the technical challenges and the work now involves drafting a business plan to begin commercial offshore aquaculture in the North Sea.

The Edulis project was the first pilot test of offshore mussel culture in a wind farm. It was a collaboration between Ghent University, the Institute for Agriculture, Fisheries and Food Research (ILVO), five private-sector partners: Belwind, Brevisco, C-Power, Colruyt Group and DEME Group, and a third research partner: OD Natural Environment. Edulis studied the feasibility of mussel culture in offshore wind farms, 30-50 kilometres off the Belgian coast. The project results included producing major evidence on:

- the biological feasibility of offshore mussel culture in the Belgian North Sea;
- the technical feasibility and requirements for a mussel culture system in the Belgian North Sea;
- the scope to integrate mussel farming with existing wind farm activities;
- the profitability of commercial offshore mussel culture farming;
- the sustainability of offshore mussel culture and the effects on seawater quality.

The Edulis project is a leading example of collaboration between the private and public sector, including research institutes, to demonstrate the feasibility of making multiple use of offshore wind farms. The Belgian government is using the results of this project to unlock multiple-use options in the Belgian North Sea.

Source: http://www.aqua.ugent.be/edulis

Case study 4-5: Flat oyster restoration on offshore wind farms (Netherlands)

In the Netherlands, the Ministry of Economic Affairs created the Dutch Flat Oyster Consortium (POC), with the support of partners including Wageningen University, WWF and Ark Natuur. The Consortium is currently assessing the feasibility (survival, growth and reproduction) of flat oyster restoration in the Dutch North Sea. The work started with a desk study commissioned in 2015. The study outlines that intense bottom-trawling activities caused the overexploitation and habitat destruction of flat oyster in the Dutch part of the North Sea. The study also concluded that proper environmental conditions for flat oyster restoration exist in the North Sea and it developed a plan to run a pilot phase consisting of four projects (Borkum Reef, Wadden Sea Survey – Shipwreck Platform and Voordelta). These and other activities narrowed the focus of oyster restoration work in current and planned Dutch offshore wind farms. The Wageningen Marine Research report 'Flat Oysters on offshore wind farms' assessed the most suitable locations for potential oyster bed restoration work, in terms of habitat features, including seabed conditions, stability and potential self-sufficiency of larval dispersal. The study is based on the premise that no seabed-disturbing activities are carried out on those sites.

This case study demonstrates the potential of using offshore wind farms as locations that can actively support nature conservation. Offshore wind farms create areas that are closed to bottom-trawling. As seabed-disturbing activities are one of the main threats to marine biodiversity in the North Sea, this is a major advantage. As such, offshore wind farms can offer tangible opportunities for nature conservation (by banning seabed-disturbing activities) and restoration (e.g. in combination with flat oysters) and can have additional potential positive effects (if combined with aquaculture).

Source: Report on Flat Oysters on offshore wind farms: http://library.wur.nl/WebQuery/wurpubs/523647

5. ONSHORE: POTENTIAL EFFECTS

5.1 Introduction

5.1.1 Types of impacts

This chapter reviews the main types of impacts from onshore wind energy development projects. Such impacts could have significant effects on habitats and species protected under the Habitats and Birds Directives.

The purpose of this chapter is to provide developers, NGOs, consultants and competent national authorities with an overview of the potential impacts for different receptor groups of EU-protected habitats and species. These impacts should be considered when developing or reviewing an onshore wind energy plan or project. However, as the identification of likely significant effects is always case-specific, the real effect of a wind energy development project on EU-protected species and habitats will be highly variable. There are clearly many cases where well-designed and appropriately sited developments have no likely significant effect, while other cases may give rise to several likely significant effects.

It is widely recognised that switching to renewable energy benefits global biodiversity in a way that is relatively straightforward to assess. However, the local interaction between a particular wind energy development and EU-protected habitats and species tends to be more complex and uncertain. For this reason, it is essential to examine each plan or project on a case-by-case basis. Ultimately, each assessment should be 'at a level of detail proportionate to the risks and probable effects and the likely importance, vulnerability, and irreplaceability of affected biodiversity' (Brownlie & Treweek, 2018).

Effects from onshore wind energy developments may arise in one or more of the five typical phases of wind energy development:

- pre-construction (e.g. meteorological equipment, land clearance)
- construction (construction of access roads, platform, turbine, etc. and transport of material)
- operation (including maintenance)
- repowering (adapting the number, typology and/or configuration of turbines in an existing wind farm)
- decommissioning (removing the wind farm or individual turbines).

It is worth noting that the potential impact of repowering may be different to that of the original project. For example, using larger turbines can increase the collision risk window (i.e. by increasing the total rotor swept area), but at the same time reduce turbine rotation speed. This could result in the risk of collision shifting from one receptor group sensitive to changes in turbine rotation speed (e.g. large birds of prey) to a receptor sensitive to total rotor swept area (e.g. bats).

When assessing the likely significant effects of onshore wind energy developments on EU-protected habitats and species, it is important to bear in mind that such effects may arise from the entire project footprint, i.e. not just from the wind turbines themselves but also from associated infrastructure. For example, we may see an impact caused by access roads, site access (e.g. for maintenance works or during construction), anemometer masts, construction compounds, foundations, temporary contractors' facilities, overhead and underground electrical connections for access to the grid, spoils, and/or any sub-station, control building, etc.

Potential impacts may be temporary or permanent. They may result from activities within or outside Natura 2000 site boundaries. In the case of mobile species, these potentially affect individuals well away from associated Natura 2000 sites. For example, a site may be designated because there are hibernating bats that breed at some distance away; mortality of those breeding individuals would affect the site's population. Potential effects may arise from the plan or project alone and may occur at different times during the project life-cycle. Plans and projects acting in combination to produce cumulative effects are of growing importance, as wind energy is expanding to meet renewable energy targets.

In the next subchapters, the types of impacts are described for each of the major receptor groups. An overview is given in Table 5-1. The description is based on an extensive literature review. Although there are still many uncertainties, in particular in the context of innovative technologies and mitigation measures, insights are growing rapidly, often thanks to an increased and improved monitoring; over the next few years much more interesting findings are expected to become available.

Table 5-1 Overview of impacts of onshore wind energy developments

Receptor	Impacts of onshore wind energy
Habitats	Habitat loss and degradation Habitat fragmentation Habitat disturbance Introduction of invasive alien species (IAS) during construction (soils contaminated with seeds from IAS) Habitat creation (habitat creation away from the wind farm to attract birds to these habitats and lead them away from the wind farm; habitat creation in intensively managed farmland by providing less intensively used residual areas) Changes in microclimate Soil compaction Indirect effects
Bats	Habitat loss and degradation Disturbance and displacement Habitat fragmentation Collision Barrier effect Barotrauma (i.e. damage to body tissues caused by a difference in pressure) Loss or shifting of flight corridors and roost sites Increased availability of invertebrate prey, and thus increased collision risk, due to night illumination Indirect effects
Birds	Habitat loss and degradation Disturbance and displacement Habitat fragmentation Collision Barrier effect Indirect effects
Other species	Habitat loss and degradation Habitat fragmentation Disturbance and displacement Indirect effects

5.1.2 Mitigation measures

After consideration of the types of impacts listed above, each sub-chapter describes possible mitigation measures to avoid or reduce the likely significant effects[73].

Mitigation measures are very important in impact assessments. If adverse impacts on the site's integrity have been identified during the appropriate assessment or cannot be ruled out, the plan or project in question cannot be approved. However, depending on the degree of impact identified, it may be possible to introduce certain mitigation measures that will avoid these impacts or reduce them to a level where they will no longer adversely affect the integrity of the site.

Mitigation measures must be directly linked to the likely impacts identified in the appropriate assessment and can only be drawn up once these impacts have been fully assessed and described in the appropriate assessment. Thus, mitigation measures can only be considered at this stage and not at the screening stage.

- The identification of mitigation measures, like the impact assessment itself, must be based on a sound understanding of the species and habitats concerned.
- Mitigation measures to avoid or reduce impacts or prevent them from happening in the first place must not be confused with *compensatory measures*, which are intended to compensate for any damage the project may cause. Compensatory measures can only be considered under Article 6(4) if the plan or project has been accepted as necessary for imperative reasons of overriding public interest and where no alternatives exist.

Mitigation measures may be proposed by the plan or project proponent and/or required or imposed by the competent national authorities. In practice, the need for mitigation measures is often acknowledged at an early stage in a plan/project's design or inception stages, for example through a 'pre-application' discussion between the developer/applicant and the

[73] Another category are what are called 'accompanying measures'. These are additional to regulatory measures of avoidance, reduction and compensation, and aim, for example, to improve knowledge on habitats or species or to carry out research projects. This is covered in Chapter 3.6 on stakeholder engagement and in particular in Case study 3-5 and Case study 3-6; it is not the focus of Chapter 4.2.

nature conservation advisers. In such cases, the need for mitigation measures is included as part of the application for authorisation (see also good practice Case study 3-6).

Mitigation measures should consider:

- avoidance: preventing significant impacts from happening in the first place
- reduction: reducing the magnitude and/or likelihood of an impact.

Table 5-2 provides an overview of potential mitigation measures in relation to a wind energy development's planning and design stages and five life-cycle phases.

Table 5-2 Types of mitigation measures (adapted from Gartman, 2016)

Measure (type)	Description
Planning, siting and design	
Macro-siting (avoidance)	This relates to the spatial planning of wind energy developments and ensures their appropriate siting from a conservation perspective. Avoiding ecologically sensitive areas (supported by, for example, wildlife sensitivity mapping) is a key avoidance measure
Micro-siting (avoidance/reduction)	Configuration of wind farm: choosing the type of turbines and their exact position[74]
Infrastructure design (reduction)	Turbine number and technical specifications (including turbine height, lighting, cable burial depth and shielding, foundation design, etc.)
Pre-construction	
Scheduling (avoidance/reduction)	Avoiding, reducing or phasing activities during ecologically sensitive periods
Alternative construction methods and barriers (reduction)	Avoiding or reducing potentially disturbing or harmful visual stimuli and emissions such as noise and vibration
Construction	
Scheduling (avoidance/reduction)	Avoiding, reducing or phasing activities during ecologically sensitive periods
Alternative construction methods and barriers (reduction)	Avoiding or reducing potentially disturbing or harmful visual stimuli and emissions such as noise and vibration
Deterrents (reduction)	Acoustic and visual methods
Operation	
Timing of turbine operation (avoidance/reduction)	Curtailment of turbine, turbine blade feathering and increasing cut-in speeds[75] (e.g. stopping turbine rotation when migratory birds are approaching at turbine height, or reducing the time that turbines are rotating)
Deterrents (reduction)	Acoustic, visual and electromagnetic measures
Rewilding access roads and/or discourage use of access roads	Once the turbines are constructed, large access roads no longer have any function (as maintenance staff can use smaller roads). Therefore they can be temporarily rewilded (until the repowering or decommissioning phase) and barriers can be installed to prevent access by non-authorised persons.
Habitat management (reduction)	Habitat management can have different applications. One approach is to make habitats unattractive in the vicinity of turbines (e.g. creating (un)attractive foraging or breeding habitats and removing carcasses to keep raptors away) combined with creating attractive habitats away from the 'risk zone' (e.g. away from areas where there is a collision risk), with the aim to dissuade and lure species away from turbines. Another approach is to create some form of biodiversity near the turbines, in particular when these are located in intensive farmland areas. This needs to be considered case by case.
Repowering	
Dismantling and relocating (avoidance/reduction)	Replacing (e.g. with higher and fewer turbines) or repositioning turbines
Scheduling (avoidance/reduction)	Avoiding, reducing or phasing activities during ecologically sensitive periods
Alternative construction methods and barriers (reduction)	Avoiding or reducing potentially disturbing or harmful emissions such as noise, vibration and electromagnetic fields
Decommissioning	

[74] The arrangement and position of turbines has a significant influence on the location of associated infrastructure; micro siting should be considered in a way that takes into account all relevant factors.
[75] 'Blade feathering' is the process of changing the angle (pitch) to reduce rotation. 'Cut-in speed' is the speed at which a turbine starts to rotate and generate electricity.

Dismantling and restoration (avoidance)	Removing turbines and associated infrastructure
Scheduling (avoidance/reduction)	Avoiding, reducing or phasing activities during ecologically sensitive periods
Alternative construction methods and barriers (reduction)	Avoiding or reducing potentially disturbing or harmful emissions such as noise and vibration

The relevance of these different types of impacts will be discussed for each main receptor group in the following chapters. Given the importance of 'macro-siting' and the strategic planning it involves, a separate chapter is dedicated to this type of avoidance measure (see Chapter 4).

Finally, as with the likely significant effects, mitigation measures should also be considered on a case-by-case basis. Distance thresholds (e.g. minimum distance to bat population breeding roosts or to bird species' foraging or nesting areas) can be applied if these are underpinned by scientific evidence. However, these should be applied cautiously and on a case-by-case basis. For example, applying a distance threshold from a bat roost may be effective at one site for a roost of one species, but may be ineffective or unnecessary for a roost of a different species at another site. Therefore, no threshold values are included in this guidance. Chapter 7 of this guidance document discusses monitoring and adaptive management. Monitoring is not a mitigation measure, but it is crucial to ensure that mitigation measures are in fact implemented and effective as predicted in the appropriate assessment. While the conclusions on adverse effects on site integrity in an appropriate assessment must be beyond reasonable scientific doubt, this does not mean that monitoring to validate such predictions is unnecessary.

5.2 Habitats

5.2.1 Introduction

Wind energy developments are typically located in exposed locations with good wind resources. Small- and medium-scale turbines are usually located on modified natural habitats close to farms, domestic or business properties. By contrast, large-scale wind energy developments are frequently located in more remote upland, coastal and open grassland areas; it is habitats in these areas which are most likely to be affected by development. Due to the increase in the height of wind turbines, there is also a trend for large-scale wind farms to use forestry land.

The following habitats must be considered in the context of an appropriate assessment:

- the natural habitat types listed in Annex I;
- the habitats of the species listed in Annex II to the Habitats Directive;
- the habitats of wild bird species listed in Annex I to the Birds Directive;
- the habitats of regularly occurring migratory bird species.

Consideration must also be given to strictly protected plant species listed in Annex IV(b) to the Habitats Directive and to the breeding sites or resting places of strictly protected animal species listed in Annex IV(a).

The scale of direct habitat loss resulting from constructing a wind energy development and associated infrastructure such as access roads, intra-array cabling[76] and sub-stations depends on the size, location and design of the project. While the actual land area under the infrastructure may be comparatively limited, the effects may be more widespread where plans or projects interfere with ecological, hydrological or geomorphological processes. Dynamic habitats such as sand dunes or wetlands are also vulnerable to any changes in their structure and functioning. This could be caused by, for instance, soil compaction, clearance of vegetation, drainage, reprofiling, etc. which may lead to effects such as erosion and habitat degradation over a wider area.

Baseline data to support an assessment of significant effects should be collected using the best available methods (see for example, Dafis *et al*., 2001; Environment Agency, 2003; Pentecost *et al*., 2009; Smith *et al*., 2011). Examples of typical baseline surveys methods are summarised in Box 5-1.

[76] Information presented in this guidance document on cabling to connect turbines is also relevant to overhead/underground electricity transmission. Detailed guidance on energy transmission infrastructure and EU nature legislation is published in a separate guidance document (European Commission (2018c).

Box 5-1 Examples of baseline survey methods for habitats

Surveys are likely to be required to delineate Annex I habitat areas within the footprint of wind energy development and normally within a defined buffer zone (e.g. a drainage basin). Detailed guidance on appropriate survey methods are in some cases available at a national level.

Identification of species and estimation of abundance of habitats:

- quadrat and/or transect surveys

Mapping the distribution of habitats:

- direct visual observation (field mapping)
- remote observation (satellite remote sensing, airborne multispectral remote sensing, aerial photointerpretation, terrestrial mapping from aerial photographs)

5.2.2 Types of impacts

5.2.2.1 What are the main types of impacts?

The main impacts on habitats are summarised in Box 5-2 and Table 5-3. Each type of impact has the potential to influence the total extent and quality of the habitat.

Box 5-2 Types of impacts on habitats

- Direct loss — the reduction of habitat extent as a result of it being removed, reprofiled or covered (e.g. from the deposition of construction materials or suspended sediments)
- Fragmentation — the conversion of a contiguous area of habitat into two or more small, isolated areas
- Degradation — the reduction in habitat quality as a result of the reduced abundance and/or biomass of species from the characteristic communities that define it
- Disturbance — a temporary change in the average environmental conditions (e.g. an increase in suspended sediments or dust deposition, or increased human presence, light and noise)
- Habitat creation – the creation or restoration of habitats as part of a set of mitigation measures
- Changes in microclimate – minor changes in air temperature and air humidity due to movement of turbine blades
- Indirect effects — habitat loss, fragmentation and degradation resulting from, for example, soil compaction, drainage, changes in grazing pressure, erosion/scour or the introduction of invasive non-native species and pollutants

Table 5-3 Types of impacts on habitats during the project's life-cycle for onshore wind energy developments

Types of impacts	Project phase				
	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss and degradation	X	X		X	X
Habitat fragmentation	X	X	X	X	X
Habitat disturbance	X	X	X	X	X
Habitat creation		X	X	X	X
Changes in microclimate		X	X	X	X
Soil compaction		X		X	X
Indirect effects	X	X	X	X	X

The impact on plant species should be carefully assessed. This is because many mountainous plant species very specific in their habitat and occupying limited areas can be widely affected, not only by the wind turbines implantation, but also by the opening of roads and the subsequent facilitated access.

Careful consideration should also be given to the potential for introducing non-native species or native species of different provenance from the local plant species present. For example, soil from other areas used in road construction may carry a seed bank with alien (invasive or not) biological material.

A number of studies have found that wind energy developments can influence microclimate up to 200 m from operational turbines (Armstrong *et al*., 2016). In particular, they can result in higher air temperature and absolute humidity at night, as well as increases in the variability in air, surface and soil temperature throughout the diurnal cycle (Armstrong *et al*., 2016). However, these impacts are relatively limited (e.g. less than 0.2 °C) and are not expected to generate likely significant effects on site integrity.

5.2.2.2 How is significance assessed?

The significance assessment always needs to be underpinned by solid scientific arguments and should refer to the conservation objectives of the site. For habitats, significance is at least determined by:

- quantifying the area of EU-protected habitat[77] predicted to deteriorate compared with the total baseline habitat area;
- the importance of the habitat for EU-protected species.

This requires a good understanding of the distribution of habitats, particularly an understanding of the feasibility of measures to avoid significant effects (see Chapter 5.2.3).

The total area of land transformation arising from a wind energy development varies according to the location and scale of the development. Land transformation is likely to be, on average, lower for cultivated land than in forests and mountainous areas.

The degree of significance is also affected by: (i) the rarity and vulnerability of the habitats affected; (ii) their importance as a feeding, breeding or hibernating place for EU-protected species; and/or (iii) their role as corridors or steppingstones for the movement of species in the wider landscape.

Wind energy developments that are placed on or near certain rare and fragile habitat types such as wetlands, blanket bogs or raised mires can potentially cause the loss or deterioration of these habitats. The concern is not just over the direct loss of an area of habitat, but over potential damage caused during construction and operation to the habitat's structure and ecological functioning. Such damage may have a significant effect over a much larger area than the direct land intake.

Peatlands in particular can be damaged by the inappropriate siting of wind energy development or associated infrastructure such as new or improved access roads. The damage is often caused because developments have not taken sufficient account of the peatland's underlying hydrology. So while the actual amount of peat lost may be small, the damage caused to its natural drainage system, for instance through drainage ditches, may have repercussions over a much wider area. Ultimately this can lead to the deterioration of a more significant area of peatland and other related habitats such as streams and other water courses located downstream.

Biological, environmental and plan or project design factors can influence the significance of effects. Box 5-3 summarises the factors typically taken into account in both the baseline data collection methods and the assessment of significance.

Box 5-3 Factors determining the baseline data collection methods and the assessment of significance, in relation to habitats

Biological

- Sensitivity, resistance (tolerance) and resilience (recovery potential)
- Presence of invasive non-native species

[77] The natural habitat types listed in Annex I, the habitats of the species listed in Annex II to the Habitats Directive, the habitats of wild bird species listed in Annex I to the Birds Directive, and the habitats of regularly occurring migratory bird species.

Environmental

- Soil or sediment type and morphology
- Air quality (e.g. dust)
- Water quality and quantity
- Existing activities such as grazing that may be displaced or excluded from the wind energy development, leading to a change in environmental conditions

Plan or project

- Wind turbine number, size, foundation design, notably its footprint area and installation methods, especially if enabling works include habitat clearance over a wider area (e.g. forest clearance)
- Cable number, length and burial methods
- Other associated activities (e.g. vehicle and material storage)

While it may be quite straightforward to quantify the effects of the wind energy development plan or project's physical temporary and permanent footprint, other effects are more difficult to quantify.

The deposition of dust, for example, may occur at some distance from a wind energy development location; depending on the site-specific factors, an assessment of significance may be appropriate. In the UK, for example, dust deposition from construction and decommissioning sites is assessed based on the presence of 'ecological receptors' within 50 m of the boundary of the site and/or within 50 m of the routes used by construction vehicles on the public highway, up to 500 m from the site entrance (Holman *et al*., 2014). It is important to note that such guidance 'cannot be too prescriptive and professional judgement is required' and that it forms part of a wider framework to ensure consistency and completeness (Holman *et al*., 2014).

Soil compaction can occur over large areas. Geotechnical survey of ground conditions can assist in quantifying the affected area and to predict the likely significance of effects on habitats. Similarly, changes in water quantity and quality can occur over large areas. In this context, hydraulic and hydrological modelling are typically used to support the assessment of significance in relation to quantifying the area of groundwater and surface water dependent habitats affected.

Where plan or project design parameters are not specific or fixed, worst-case assumptions must be made. For example, inter-array and transmission cabling can substantially increase the footprint of habitat loss associated with wind energy development. It may be the case that at the time of the strategic environmental assessment, environmental impact assessment or appropriate assessment, the exact cable route may not be known, but may be assumed to lie somewhere within a wider corridor between the generating infrastructure and the transmission grid connection.

An example of a significance framework for assessing effects of windfarm construction on steppic grasslands in Romania is presented in Case Study 5-1.

Case Study 5-1 Effects on steppic grasslands by construction of wind turbines in Dobrogea (South-eastern Romania)

The construction of wind turbines (Figure 5-1) can cause substantial loss and fragmentation of habitat. In this example the focus is on steppic grassland habitats. The Dobrogea region of Romania still has large areas of Ponto-Sarmatic steppe habitats (priority habitats 62C0, 40C0) but their area is decreasing and habitat quality is declining due to a number of reasons: afforestation, quarrying, overgrazing and construction works. As a result, these habitats are under serious threat and the associated wildlife, such as *Spermophilus citellus* (European Ground Squirrel, European Souslik), an Annex II mammal species, is endangered.

Independent research on behalf of the European Commission investigated the individual and cumulative effects of several planned (and partly executed) windfarm developments in Dobrogea (Arcadis, 2010). A significance framework was drawn up for several impact groups. With regard to habitat loss and habitat degradation (including fragmentation) the following criteria were applied to define significance:

Significant:

- Any additional area of priority habitat (62C0, 40C0) within the site of community importance (SCI) is deteriorated by direct habitat loss
- Any additional area of priority habitat (62C0, 40C0) within the SCI is deteriorated by fragmentation

- Any additional disturbance to Annex II and/or Annex IV species associated with the priority habitat (62C0, 40C0) which might affect their conservation status

Non-significant:

- No priority habitat is affected, neither by direct habitat intake nor fragmentation, nor by disturbing the Annex II and IV species associated with this habitat type

This was justified as follows:

- Priority habitats: (i) priority habitats need a much stricter protection scheme than other Natura 2000 habitat types; (ii) this habitat type has a very limited range in its biogeographical area within the EU; and (iii) this habitat type is under serious threat for numerous reasons (intensification of agriculture, climate change, and other activities such as quarry developments). For these reasons, any additional area of priority habitat (62C0, 40C0) within the SCI that was deteriorated was considered as significant, as this would immediately affect the conservation objectives for this habitat type.
- Annex II and/or Annex IV species associated with the priority habitat: disturbance of Annex II and Annex IV species was considered significant as soon as their conservation status might be endangered. This is the case when a project might contribute to: (i) the long-term decline of the species' population on the site; (ii) the reduction or the risk of reduction of the species' range within the site; and/or (iii) the reduction of the size of the species' habitat within the site.

Direct habitat loss is mainly caused during the preparatory and construction phases. The total extent of habitat destruction in each Natura 2000 site has been estimated in a quantitative way based on: (i) calculations – and verification by field surveys – of the average surface intake for one wind turbine (turbine base, turbine platform, access road network); and (ii) the location of the wind turbines. The average area of direct habitat loss could be estimated at 3 000 to 4 000 m^2 (covering the construction of the turbine + access roads) per wind turbine:

- Habitat destruction and degradation starts already during the pre-construction phase, as for most wind farms first a meteomast is constructed, which is a light structure with a base of maximum +/- 50 m^2.
- Most damage, however, is caused during the construction of the wind farm itself. Turbine construction requires extensive ground works, involving excavations and building large concrete foundations for the pylons. When placed in rocky soil, for each turbine an area of about 100 m^2 (1 to 2 m deep) is excavated for the base of the turbine itself and a nearby platform is created, covering a huge area (at least 1 000 m^2 and sometimes up to 2 000 m^2).
- Wide access roads (width 4.5 – 5.0 m on average) (see Figure 5-1) are built to enable heavy lorries to reach the turbine locations. Analysis of environmental approvals indicates that this area amounts to almost 2 000 m^2 on average for each turbine.

Figure 5-1 Habitat loss and fragmentation by construction platforms and access roads in hilly steppe landscape

Habitats may also be affected by fragmentation. The network of access roads fragments habitat structure, resulting in a patchwork of small remnants of habitat crossed by broad gravel roads (see Figure 5-1). Many studies[78] demonstrate the negative effects of habitat fragmentation caused by such roads on reptiles, amphibians and small mammals. These studies also describe the difficulties involved in calculating the size of the affected area.

The affected area includes an area around the turbines and the whole area in between, excluding the areas in between separate parts of the wind farm. Figure 5-2 shows that the area potentially affected by fragmentation is very dependent on the outside radius (i.e. distance from turbines) considered when delineated the affected area (600 m in the left picture and 200 m in the right picture). For the purposes of this research, the whole area within a wind farm and an outer boundary of 200 m from the outer wind turbines was considered as the minimum area potentially affected by fragmentation. As mentioned before, the exact area that might be affected is very difficult to predict as it depends on the exact location and density of the access roads, and on the spatial distribution of the local populations of mammals and reptiles. The approach described is actually an underestimation, as the main access road between the existing road network and the wind farm also contributes to fragmentation but is not included in the calculation.

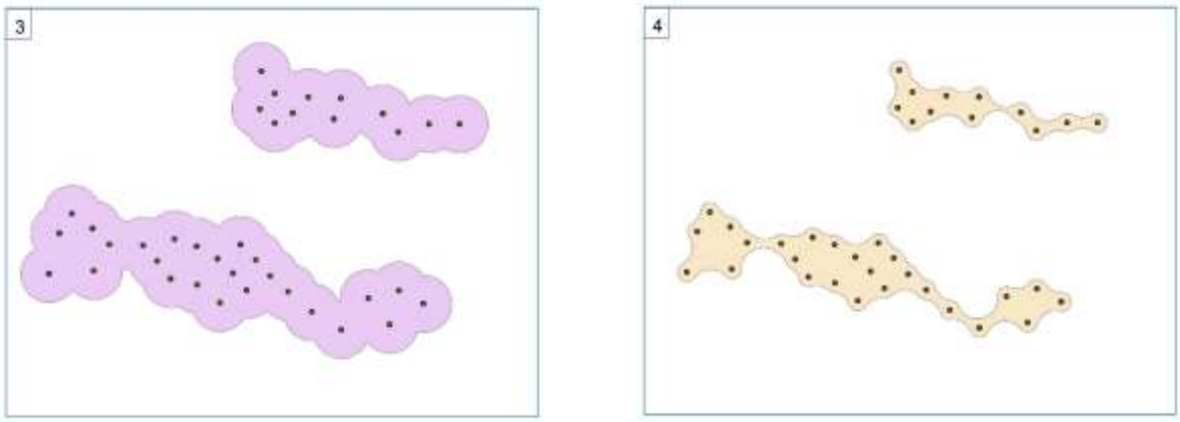

Figure 5-2 Visualisation of the approach used to calculate the area fragmented by a wind farm

Source: Technical assessment of the potential effects of the construction and operation of wind farms in northern Dobrogea (Romania) (Arcadis, 2011)

To summarise, a number of key recommendations for assessing the significance of effects on habitats are presented in Box 5-4.

Box 5-4 Key recommendations for assessing the significance of effects on habitats

- Draw up a solid significance framework based on criteria referring to the conservation objectives for the habitats concerned and their associated Annex II and Annex IV species, which are context-specific (case by case) and scientifically well underpinned.
- Ensure data availability, notably in relation to broad-scale habitat distribution, to feed into plan-level assessments or a detailed project-specific survey and assessment.
- Consider the spatial and temporal variability of habitats in dynamic systems, for example habitats in flood plains or coastal sand dune systems, particularly when considering the effects of climate change over the operational life of the wind energy development.
- Acquire knowledge of and insights into the sensitivity of habitats and associated species to wind energy development activities, in particular their resistance (tolerance) and resilience (ability to recover).
- Make use of the increased availability of post-development monitoring reports to improve the evidence base.

[78] Fahrig, 2003.

5.2.3 Potential mitigation measures

For habitats affected by onshore wind energy development, it is clear that the appropriate siting of wind energy development, including access roads, is the most effective way to avoid significant effects on the EU's protected habitats (macro-siting). This can be best achieved by strategically planning wind energy developments over a broad geographical area. If EU-protected habitats cannot be avoided, the careful placement of individual turbine associated infrastructure (micro-siting) may be a good way of avoiding these habitats' most sensitive and/or valuable parts.

Habitats which are degraded during the construction phase (e.g. storage of soils and equipment) should be restored as soon as construction is completed. Access roads could be closed for unauthorised people or could even be reduced in size.

5.3 Bats

5.3.1 Introduction

UNEP/EUROBATS has published comprehensive European guidance in relation to bats and wind energy, 'Guidelines for consideration of bats in wind-farm projects' (Rodrigues *et al*. 2015). This chapter summarises the information related to the possible impacts of onshore wind energy developments on bats, drawn from the UNEP/EUROBATS Publication No. 6 and supplemented by additional literature published since 2014. A list of national guidance documents relevant to bats is given in Appendix E.

The information provided in this chapter is relevant to bat species listed under Annex II and Annex IV of the Habitats Directive. Evidence indicates that wind energy developments affect bat species listed in Annex II less than those listed in Annex IV. The nyctalus and pipistrelle species, which are not included in Annex II, make up over 90% of the recorded wind-farm casualties (see Table 9-6 in Appendix E), whereas Annex II species collectively represent less than 0.5% of casualties[79].

Baseline data to support an appropriate assessment should be collected using best practice survey methods, as described in the UNEP/EUROBATS guidelines. Where relevant, this Europe-wide guidance should be considered in conjunction with national or regional guidance in order to adopt appropriate and scientifically robust methods relevant to the species, habitats and environmental conditions specific to individual Member States or European regions. Surveys need to take into account the full cycle of bat activity throughout the year, provide information about roosting (breeding, mating/swarming, hibernation), foraging, and commuting by local bat populations, and identify likely bat migration routes. The spatial scale of the surveys needs to be carefully considered bearing in mind the size and location of the wind energy development and its area of influence (see Chapter 3.2). Examples of baseline surveys are summarised in Box 5-5.

Box 5-5 Examples of onshore baseline surveys for bats (adapted from the UNEP/EUROBATS guidelines, Rodrigues *et al*. 2015)

- Identification of important maternity, hibernation and swarming sites based on signs of bats and/or presence and abundance of recorded bats.
- Bat detector surveys on the ground — use of automated detectors to the define bat activity index (number of bat contacts per hour) and habitat use, potentially supplemented with manual surveys (walked transects, vantage-point surveys) and other observational techniques (thermal/infra-red cameras).
- Activity surveys at height — use of automated detectors to define the bat activity index (number of bat contacts per hour).
- Potential need for above-canopy activity surveys and advanced techniques such as trapping and radio-telemetry in woodlands[80].
- Collection of environmental data (temperature, precipitation, wind speeds).

[79] Source: The report of the EUROBATS IWG Meeting 23 on wind turbines and bats presented to the Advisory Committee (https://www.eurobats.org/sites/default/files/documents/pdf/Advisory_Committee/Doc.StC14-AC23.9_rev.2_Report_Wind_Turbines.pdf)

[80] Muller *et al.* (2013) found open-habitat bat species and *Pipistrellus* species regularly forage not only in clearings or forest meadows, but also above the canopy of closed mature stands, behavior that may put them at risk from turbines in such locations.

5.3.2 Types of impacts

5.3.2.1 What are the main impact types?

The main types of impact on bats are summarized in Box 5-6 and Table 5-4. Each impact type has the potential to influence the survival rates and reproductive success of individuals, which can result in changes in the demographic parameters of a population, the outcome of which may be a measurable change in the population size.

Box 5-6 Main types of impacts on bats (drawn from the UNEP/EUROBATS guidelines)

- Collision and barotrauma — the fatal interaction between bats in flight and wind turbine structures.
- Habitat loss and degradation — the removal of, fragmentation or damage to supporting habitats.
- Disturbance and displacement at roost sites — activities in and around roost sites such as habitat removal or the presence of maintenance vehicles and personnel can result in changes in temperature, humidity, light, noise and vibration within the roost, with a consequent reduction in use or reproductive capacity.
- Loss of flight corridors and roost sites — the physical or functional loss of flight corridors and roosting sites.

Table 5-4 Types of impacts on bats during the project's life cycle for onshore wind energy developments

Types of impacts	Project phase				
	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss and degradation	X	X	X	X	X
Disturbance and displacement at roost sites	X	X	X	X	X
Habitat fragmentation		X	X	X	
Collision			X	X	
Barrier effect			X	X	
Barotrauma			X	X	
Loss or shifting of flight corridors and roost sites		X	X	X	
Increased availability of invertebrate prey, and thus increased collision risk, due to night illumination			X	X	
Indirect effects		X	X	X	X

Once the wind turbines are in operation, mortality due to collision or barotrauma are considered to be the most significant effects, but the risk differs between species.

Disturbance and displacement could occur at any stage of a project's life cycle, with barrier effects occurring during operation and repowering. These likely significant effects could result in changes in behaviour including attraction (Behr *et al*. 2018; Foo *et al*. 2017), spatial shift of flight corridors, and the exclusion of bats from foraging habitats they would otherwise use (Barré *et al*. 2018). Attraction could result in higher collision risk (Rydell *et al*. 2010a; Voigt *et al*. 2018). However, Millon *et al*. (2018) considered displacement itself to be an important impact to consider, and Barré *et al*. (2018) have recently quantified this effect across a number of wind farms. The assessment of disturbance, displacement and barrier effects should be considered on a case-by-case basis, taking into account the size of the plan or project, the bat species known to be present, their habitat use, and the importance of the supporting habitat to the favourable conservation status of the population, particularly in the light of existing threats and the site's conservation objectives.

5.3.2.2 How is significance assessed?

Biological, environmental and plan or project design factors can influence the assessment of significance of effects on bats. The main factors taken into account in both the design of baseline data collection methods and the assessment of significance are listed in Box 5-7.

Box 5-7 Factors for the design of baseline data collection methods and the assessment of significance, in relation to bats

Biological

- Collision risk, to a large extent defined by foraging characteristics, echolocation type and the flight behaviour of species (Denzinger and Schnitzler, 2013; Roemer *et al*., 2017).
- Annual life cycle stage, i.e. active, hibernating, breeding, migrating, swarming.
- The presence of hibernation and maternity roosts.
- Population vulnerability, based on collision risk and the status of species affected (an example can be found in Scottish Natural Heritage *et al*., 2019).

Environmental

- The presence of habitats within 200m of a plan or project likely to be used by bats during their life cycle, e.g. forests (especially mature broad-leaved forests), trees, hedgerow networks, wetlands, waterbodies, watercourses and mountain passes[81].
- Confined areas where bats forage or roost, and/or the potential for narrow bat migration or commuting routes[82].
- Large river corridors that may serve as migration routes[83].
- Habitat types at a landscape scale, e.g. the presence of broadleaved woodland within 1.5 km of wind energy developments in Great Britain appeared to reduce risk to all species combined (and soprano pipistrelles analysed separately), but the total area of coniferous woodland was only associated with an increased risk to noctules (Mathews *et al*., 2016). The responses are therefore species- and habitat-dependent. Depending on the species in question and their habitat associations, the presence/absence of a suitable habitat could be used as a way of 'ruling in' areas potentially suitable for wind energy developments rather than for identifying areas likely to be problematic (Mathews *et al*., 2016).
- Wind speed and direction, temperature and relative humidity are known to be significantly correlated with both bat activity and mortality (Amorim *et al*. 2012; Mathews *et al*. 2016; and others cited in Rodrigues, 2015). These environmental variables may be among those used to determine the level of risk a proposed site is likely to have on bats.

Plan or project design

- Turbine number and rotor swept area.
- Turbine size, which can influence the distance over which displacement occurs [Barré *et al*. (2018) and Minderman *et al*., (2012; 2017)].

Fatality research studies carried out in the last few years (see

[81] There is evidence that the removal of trees in forested areas benefits some species by increasing forest edge but can consequently increase bat activity leading to potentially higher collision risk (Rodrigues et al. 2015).
[82] Furmankiewicz & Kucharska (2009) investigated the migration of bats along the Oder River valley in southwestern Poland and concluded that river valleys are migration flyways for bats that travel long distances and those that travel short distances, and that differences between spring and autumn migration may be related to food supply, energy demands, seasonally different routes or a combination of these factors.
[83] In contrast, Meschede et al. (2017) concluded that bat migration occurred everywhere (even mountains were not excluded), and that it was unlikely that mapping migration routes would be possible or meaningful. Nonetheless, river valleys and similarly productive areas are important as stopover sites for foraging and breeding, and are therefore of population-sustaining significance for migrating species.

Table 9-6 in Appendix E) have shown that wind turbines could affect different bat species in a different way, due to bats' different behaviour and flight styles. Bat species that fly and forage in open space (aerial hunters) are at high risk of collision with wind turbines. Some of these species migrate long distances at high altitudes, which also increases the collision risk (e.g. *N. noctula, P. nathusii*). In contrast, bats that tend to fly close to vegetation run a lower risk of colliding with wind turbines.

In Table 5-5, the degree of collision risk from wind turbines in open habitats is shown for European and Mediterranean species. Where wind turbines are built in broadleaved or coniferous woodlands or on woodland edges, this may significantly increase the collision risk for some species.

Table 5-5 Collision risk for European (incl. Mediterranean) species from wind turbines in open habitats (derived from Rodrigues, 2015)

High risk	Medium risk	Low risk
***Nyctalus* spp.**	*Eptesicus* spp.	*Myotis* spp.
***Pipistrellus* spp.**	*Barbastella* spp.	*Plecotus* spp.
Vespertilio murinus	*Myotis dasycneme*[2]	*Rhinolophus* spp.
Hypsugo savii		
***Miniopterus schreibersii*[1]**		
Tadarida teniotis		

[1] *Miniopterus schreibersii* is the only Annex II species in the high-risk category

[2] in water-rich areas.

The annual life cycle of bat species must also be taken into account as the magnitude and significance of an effect can vary depending on the time of year (Table 5-6). The timing of annual life cycle stages varies between species and populations of the same species in different Member States. It is therefore prudent to refer to national guidance in relation to bats and wind energy developments, where this is available, or to the UNEP/EUROBATS guidelines (Rodrigues *et al*. 2015) if there is no national guidance. A comprehensive list of national guidance documents is provided in Appendix E.

Table 5-6 The degree of risk associated with impacts on bats in relation to their annual life cycle (drawn in part from Rodrigues et al. 2015).

Likely significant effect	Breeding season	Hibernation season	Spring/autumn
Construction			
Habitat loss and degradation	Low to high, depending on proximity to roosts	High, depending on proximity to roosts	Low (particularly for migrating bats travelling long distances)
Loss of roost sites	Potentially high or very high	Potentially high or very high	Potentially high (e.g. loss of mating roosts)
Turbine operation			
Collision/fatalities	Low to high, depending on the species	Low	High to very high
Loss or shifting of flight corridors	Medium	Low	Low. Migration likely to occur on a broad front, but cumulative effects need to be considered

Risk-based approaches use baseline data to identify foraging areas and commuting/migratory corridors with relatively high bat activity and species richness together with important roost sites.

Predictions of bat mortality resulting from wind turbine collisions have to date largely been made based on case studies on individual wind farms, rather than multi-site studies. This makes it difficult to study underlying relationships between potential risk factors (e.g. turbine height, proximity to woodland, etc.) and casualty rates, as the risk factors do not vary within sites (Mathews *et al*., 2016). Developing and verifying theoretical, habitat and species distribution-based risk models is an “important next step” (Arnett, 2017), but challenges related to a lack of habitat specificity for high-risk species remain.

Some approaches used to estimate bat mortality and determine significance are reviewed in Rodrigues *et al*. p.38 (2015) and Laranjeiro *et al*. (2018). These include species distribution models (SDMs), individual-based models[84] (IBMs), population-based models, and index-based models. A comprehensive review of methods used to estimate fatality is provided in Marques *et al*. 2018. More than two approaches may be combined to inform an appropriate assessment; for example, an individual-based model used to predict the collision mortality rate may be followed by a population-based model to assess the potential consequences of additional mortality on the population. There is no reason why other approaches cannot be used, if they have a logical or empirical basis.

Typical challenges encountered in the assessment of likely significant effects on bats that may require additional baseline data collection or the application of the precautionary principle are summarised in Box 5-8.

Box 5-8 Key challenges in assessing the significance of effects on bats

All effects

- Limited evidence regarding the effects of small wind turbines, e.g. those with a hub height less than 18 m above ground level.
- Limited evidence regarding the behaviour of bats around turbines (Natural England, 2014[85] and Mathews *et al*. 2016). Some evidence of attraction has been reported (Behr et. al., 2015), particularly in the presence of red light (Voigt *et al*. 2018).
- In a British wind park, bat activity showed extremely high variability, both within and between years (Mathews *et al*., 2016).

Collision

- There is no way to predict bat fatalities prior to construction with current approaches focused on site-specific surveys rather than multi-site studies, which makes it difficult to identify risk factors (Mathews *et al*., 2016). Arnett *et al*. (2016) identified improving the predictability of bat fatalities as a key area for future research.
- It remains unclear whether pre-construction acoustic data are able to adequately predict post-construction fatality (Arnett *et al*., 2013), and whether current environmental impact assessments fail to reduce the risk of bat casualties on wind farms (Lintott *et al*. 2016).
- It is possible that there are additional high-risk periods in the annual life cycle of bats, but that they remain undetected because of a focus on late summer/autumn, a period coinciding with both autumn migration and the beginning of the presumed mating period in many of the studied species (Rydell *et al*., 2010; Rodrigues *et al*., 2015).
- Search protocols might not identify all casualties, though techniques are improving, particularly with the use of dogs[86]. Injuries that allow bats to travel out of the typical search area before dying ('cryptic deaths') may mean bat mortality estimates are generally underestimated(Barclay *et al*., 2017). Fatalities from turbines with greater nacelle/rotor heights may also fall outside the search area and be missed (Weber *et al*. 2018).
- There is some evidence of sex- and age-specific vulnerability to collision (Lehnert *et al*. 2014) but this has not been found in all studies (Barclay *et al*., 2017, Mathews *et al*. 2016). The predicted effects on local populations depend heavily on the age and sex structure of casualties, so this is an important data gap.
- There are limited mortality estimates for wind energy developments located along migratory flyways (Rydell *et al*., 2010a).

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[84] See for example Roemer et al. (2017) or Rijkswaterstaat (2018) for offshore.

[85] These guidelines from the UK are superseded by Scottish Natural Heritage et al. (2019)

[86] Most methods used to estimate fatality rate are supported by data from carcass searches carried out around wind turbines. It has been found that searcher efficiency and survey coverage affect precision of fatality estimates (Reyes *et al*., 2016). Trained search dog teams seem to be more effective and efficient at identifying dead bats than people are (Mathews *et al*., 2013, Mathews *et al*., 2016, Reyes *et al*., 2016). This is due to the difficulty with identifying bat carcasses, particularly in moorland and arable habitats where vegetation cover is likely to conceal carcasses. Whether conducted by people or dogs, the number of bat carcasses would be a minimum estimate of the true casualty rate due to carcass removal by scavengers, decay (Paula *et al*., 2015) and weather (Mathews *et al*., 2016).

- The effects of mortality on populations is extremely poorly understood (Weber *et al*. 2018, amongst others)[87 88 89].

Disturbance and displacement

- There is limited empirical data on the significance of disturbance and displacement, except in relation to the disturbance of roost sites.
- The extent to which wind farms may displace foraging bats is uncertain but may be important for a broad range of species, and may result in effects on species not considered to be at high risk of mortality (Barré *et al*. 2018).

Barrier effect

- The cumulative barrier effect on long-distance migrants of avoiding multiple obstacles along the course of their migration route remains unstudied.

Habitat loss and degradation

- The extent of functionally linked land that lies beyond the borders of a Natura 2000 site and is necessary to maintain or restore the favourable conservation status of a species is unknown and varies between species (e.g. Apoznański *et al*. 2018). As noted, however, the majority of species vulnerable to collision risk are not Annex II species.

Loss of flight corridors and roost sites

- Empirical data on the significance of the loss of flight corridors is limited.
- Wind turbines may influence populations outside their national borders through effects on migrating bats (Voigt *et al*., 2012; Lehnert *et al*., 2014).
- Connectivity between breeding and wintering areas may be weakened as the increasing cumulative density of wind energy developments disrupts national and transboundary migratory routes (Berkhout *et al*.,2013).

To summarize, a number of key recommendations for the assessment of likely significant effects on bats are summarised in Box 5-9.

Box 5-9 Key recommendations for assessing the significance of effects on bats

- Define clear significance criteria that are aligned with the conservation objectives for the bats concerned, are context specific (case-by-case) and are scientifically underpinned.
- Ensure availability of data, notably in relation to bat populations, their activities, their roost sites, etc. to inform plan-level assessments or detailed project-specific surveys and assessment.
- Invest in research in order to cover the knowledge gaps, as listed in Box 5-8.
- Benefit from the increased availability of post-development monitoring reports to improve the evidence base.

5.3.3 Potential mitigation measures

5.3.3.1 Introduction

This section provides an overview of possible mitigation measures that have been proposed or applied with reference to wind energy developments and bats. It should be noted that mortality, the most significant effect,

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[87] This is particularly important as some authorities set limits on mortality attributable to turbines in operation (e.g. Weber et al., 2018) despite the impact of mortality being unknown.
[88] In the USA, Frick *et al*. (2017) used models to assess the hoary bat, the species most frequently killed by turbines in North America, and found that mortality may drastically reduce population size and increase the risk of extinction. However, because baseline data on the population of bats killed is lacking (Natural England, 2014; Rodrigues *et al*., 2015), the effects of wind turbines on local bat population data cannot be separated from other variables (Rodrigues et al., 2015; Huso *et al*., 2014). Even some large-scale projects (such as that conducted by Mathews *et al*., 2016) have been unable to conclude whether or not there is an impact on local or national bat populations.
[89] An additional challenge relates to using certain thresholds (e.g. 1-5% for birds). The Council of State in The Netherlands declared that “a threshold of 1% of annual mortality (which was used for birds) can also be used for bats” (Heijligers *et al*. 2015). However, in most cases, there is insufficient information about bat population size and the possible impact. Sometimes arbitrary (decision) thresholds are applied, e.g. the threshold of max. 2 bat fatalities/turbine/year is used (Voight *et al*. 2015), although this is not necessarily consistent with national and EU legislation, especially for endangered species (Voight *et al*. 2015). See summary in Everaert J. (2017).

is not easily mitigated once turbines are operational. There is still uncertainty as to whether some of the measures listed will avoid or reduce a significant effect; the curtailment or increase of cut-in wind speeds still remain the only proven ways to reduce bat fatalities at operating wind farms (Arnett, 2017).

Although macro-siting can contribute to mitigating risk, it is more challenging for bats, because the most affected bat species tend to be common and widespread, rather than habitat specialists. The extent to which macro-siting can play a role in bat conservation in practice is therefore not totally clear, although macro-siting definitely has its remits in avoiding areas with habitat characteristics that are clearly more attractive to bats.

The following sections provide a brief description of the possible mitigation measures once the location for the wind energy development has been chosen.

Table 5-7 Possible mitigation measures for bats (A: avoidance; R: reduction)

	Collision and barotrauma	Habitat loss and degradation	Disturbance and displacement at roost sites	Loss of flight corridors (barrier effects) and roost sites
Micrositing: Turbine arrangement and location	A/R	A/R	A/R	A/R
Infrastructure design: Turbine number and technical specifications	R		R	R
Scheduling: Avoiding, reducing or phasing construction activities during ecologically sensitive periods			A/R	
Curtailment and cut-in speeds: Turbine operation timing	R			R
Deterrents: Acoustic and visual measures	A/R			R

5.3.3.2 Micro-siting: Turbine arrangement and location

It is essential to have a full understanding of the location and use of bat roosts and flight activity over the entire zone of influence of the wind energy development in order to place turbines in the best possible way and effectively minimise their effects. This can be achieved by using the data collected from detailed baseline surveys undertaken early enough in the project's development to influence the front-end engineering and design (FEED). Wind turbines should be sited away from areas of high bat activity or roosts. Minimum distances from woodlands and linear features (used as commuting routes) are cited in the UNEP/EUROBATS guidelines and some national guidelines[90].

[90] For example: latest UK guidelines (2019), see: https://www.nature.scot/sites/default/files/2019-01/Bats%20and%20onshore%20wind%20turbines%20-%20survey%2C%20assessment%20and%20mitigation.pdf

5.3.3.3 Infrastructure design: Turbine number and technical specifications (including lighting)

Turbines vary considerably in height and blade length. Mathew *et al*. (2016) reported an increasing risk to bats with larger rotor sizes in a British wind park: each metre increase in blade length was associated with an increase of approximately 18% (95% confidence intervals, 5% to 32%) in the probability of a casualty (of any species) occurring. Rotor size and mast height are correlated, with rotor size being the strongest predictor. While taller turbines are connected with more casualties, this is likely to be because they also have larger rotors. Therefore, reducing the size of the tower while keeping rotor size the same is unlikely to result in fewer casualties.

Past studies have shown that, in general, bats respond to artificial light at night according to the emitted light colour, and that migratory bats in particular exhibit phototaxis[91] in response to green light. Research suggests caution in the application of red aviation lighting, particularly at wind turbines, as red light may attract bats, which would eventually lead to a higher collision risk for migratory bats. Conversely, avoiding the use of red light may reduce bat casualties; however, possible conflicts with aviation standards would need to be considered here.

5.3.3.4 Scheduling: Avoiding, reducing or phasing construction activities during ecologically sensitive periods

The UNEP/EUROBATS guidelines for considering bats in wind-farm projects provide guidance on scheduling construction activities:

- avoid the vicinity of occupied hibernacula and nursery roosts and the time of year when they are used;
- in general, avoid the time of day and year when bats are actively foraging and commuting;
- phase the activities so that the entire site is not subjected to disturbance at the same time; and/or
- phase the activities so that the programme for certain disturbing activities or construction of certain areas within the development occurs when bats are least sensitive to the disturbance.

In order for these measures to be effective, it is essential to have a full understanding of the location and use of bat roosts and flight activity over the entire zone of influence of the wind energy development.

5.3.3.5 Curtailment and cut-in speeds: Timing of turbine operation

Normally, turbines ‘freewheel’ at wind speeds below the cut-in speed (the lowest wind speed at which turbines generate power). Turbine activity can be reduced in three ways: a) blade feathering (so they are parallel to the prevailing wind, effectively reducing their surface area), b) raising the cut-in speed, and c) employing methods to stop the blades turning at lower wind speeds[92] (Rodrigues *et al*., 2015; Arnett, 2017). According to evidence from Europe and North America, curtailment and the increasing of cut-in speeds are the only proven ways of reducing bat collision mortality (Rodrigues *et al*., 2015; Behr *et al*. 2017).

These methods are supported in the more recent Mathews *et al*. (2016), which recommends restricting the rotation of turbine blades as much as possible below the cut-in speed. This means that the amount of time the blades are turning at low wind speeds can be reduced without incurring any loss of energy generation.

The cut-in speed for a wind energy development should be determined on a case-by-case basis because bat activity is influenced by wind speed and other meteorological variables and may differ significantly between species, years, sites, countries and regions. In order for these measures to be effective, it is essential that the cut-in speed threshold for a wind energy development is based on detailed baseline survey data collected in accordance with the most recent good practice guidelines (i.e. UNEP/EUROBATS guidelines). For this purpose, bat activity data need to be collected in tandem with environmental variables, of which the most important is wind speed.

Scottish Natural Heritage (2019). Bats and Onshore Wind Turbines: Survey, Assessment and Mitigation
[91] Movement of an organism towards or away from a source of light.
[92] Feathering is preferred; braking (making the blades stop completely) is used in emergencies, but repeated use would damage the turbine.

Researchers in Germany (Behr *et al*, 2018) have developed free software ('ProBat 6.1'[93]) to calculate curtailment algorithms for wind farms. This application is presented in Case Study 5-2 below. It requires bat activity data recorded at the nacelle of operational turbines to cover a sufficiently large time period, including the main period during which bat activity is high. The application calculates turbine-specific cut-in wind speeds to reduce mortality to a specified level, and offers the option of estimating the loss in revenue from curtailed operations.

Radar has been used in the US to trigger curtailment in the presence of birds, particularly large raptors. This has proved less suitable for bats. However, one project in the western US has set up infrared sensors at the entrance to a cave roost to trigger when the bats exit the cave in the evening. The project initially used radar to assess both bird and bat risk at the site, but now rely entirely on data from the infrared sensors to determine whether to curtail the wind turbines on a nightly basis[94]. This is a low-cost low-input solution to highly variable cave occupancy.

Case Study 5-2: RENEBAT II and RENEBAT III / ProBat

Curtailment programmes sometimes use wind speed alone, or wind speed and other variables. The RENEBAT project collected data from bat fatality searches and from bat acoustic activity measured at the nacelle to test curtailment algorithms for previously identified high-risk turbines. Sixteen turbines were run with and without curtailment programmes (alternating each week for a period of 14 weeks). The aim was to reduce mortality under curtailment ('bat-friendly' operation) to 0.012 fatalities per turbine per night (equivalent to two fatalities per turbine per year). The 'bat-friendly' operation also included a hysteresis[95] of 0.5 ms-1, designed to reduce wear on turbine components by reducing the number of cut-in events.

During the experiment, the area below the turbines was searched for carcasses on a daily basis and the acoustic activity was continuously sampled at the nacelle. In total, 21 bat fatalities were found during the seven weeks of 'normal' operation, and three bat carcasses were found during the seven weeks during which the wind turbines were operating in 'bat-friendly' mode. The mean collision rate calculated based on the fatality searches (corrected for scavenger removal and searcher efficiency) was 0.064 bat fatalities per wind turbine per night for nights with 'normal' operation and 0.010 for nights with 'bat-friendly' operation. Thus, the actual fatality rate during 'bat-friendly' operation differed only marginally from the target value of 0.012 dead bats per wind turbine per night. The actual loss in energy yield was calculated during 'bat-friendly' operation, as was the expected loss for times with 'normal' operation if turbines had been running in 'bat-friendly' mode: the result was an average loss of 2.1 % of annual wind-turbine energy yield for 2012. Since the wind turbines selected for the experiment had a particularly high collision-risk, the value for a randomly selected dataset of wind turbines (70 turbines sampled in 2008) was lower: on average 1.8 %. If no hysteresis was used, this value dropped to 1.4 %. Thus, the statistical models were able to predict fatality rates of the sampled wind turbines with a high level of accuracy, and the 'bat-friendly' curtailment algorithms were shown to reduce residual collision risk to a pre-set value with high precision.

The software (ProBat) is now available for use throughout Germany, and is a requirement in some federal states. It accounts for regional variation, includes some level of species differences in collision risk[96], and can accept three different models of bat detector data. Its applicability/accuracy in other areas of Europe (and to a broader range of species and bat activity data) would need to be tested. In addition, the sizes of turbines and rotors on which the system was tested were relatively small compared to the usual sizes of new turbine installations, and so applicability to larger installations also needs to be verified.

Source: Behr *et al* 2015, 2018; Weber *et al*. 2018

[93] http://windbat.techfak.fau.de/tools/index_en.shtml

[94] Research on the use of infrared technology for proactive bat roost management was presented at the annual meeting of the Western Section of the Wildlife Society (February 2019), and is summarized here: https://www.nationalwind.org/nwcc-2019-wind-wildlife-year-in-review/

[95] This means that, during times with a 'bat-friendly' cut-in wind-speed of, for example, 5.0 ms-1, the rotors stopped when the wind-speed dropped below 5.0 ms-1 but only started rotating again when the wind-speed exceeded 5.5 ms-1.

[96] Nathusius' pipistrelle (*P. nathusii*) showed an activity pattern that differed from other bat species in several aspects (distribution of activity over the night and throughout the year, and correlation of activity and wind speed), which Weber *et al*. (2018) considered to be (probably) due to migratory behavior.

5.3.3.6 Deterrents: Acoustic measures

Ultrasound has been used as a mitigation tool to deter bats from turbines and thereby reduce mortality[97]. Arnett *et al*. (2013) provide evidence that broadband ultrasound broadcasts can reduce bat fatalities by discouraging bats from approaching sound sources. The effectiveness of the ultrasound deterrents studied at that time was limited by distance and the area that ultrasound can broadcast, in part due to its rapid attenuation in humid conditions.

Since then, more effective deterrents have been developed in the US and will soon be available commercially (see Case Study 5-3).

Case Study 5-3: Use of ultrasonic acoustic devices (UADs) as a bat deterrent technique

Bat Conservation International's wind programme team, in collaboration with Texas State University, carried out research to test the effectiveness of UADs mounted on the wind turbines themselves. Functionality is based on the assumption that the UADs 'jam' the bats' echolocation or make the airspace around the turbine aurally uncomfortable, thereby keeping bats away from potentially dangerous rotating turbine blades. The UADs emit a loud, high-frequency noise that overlaps with the signals bats use to navigate and capture prey.

Duke Energy's facility in south Texas comprises 255 wind turbines (Vestas V-110, 2 megawatts), feathered to the manufacturer's cut-in speed (3.5 m/s). Sixteen wind turbines were monitored on each night: eight control and eight treatment turbines, randomly assigned on a nightly basis. Mortality searches were carried out across 100-metre radius search plots between July 31 and October 30 in 2017 and 2018.

In 2017, there were 303 fresh bat fatalities of seven species (78% Brazilian free-tailed bats). Almost twice as many casualties were found in the control areas (65% control; 35% treatment). The situation was similar in 2018: 325 fresh bat fatalities of five species (77% Brazilian free-tailed bats). The casualties were distributed similarly: 68% control; 32% treatment. Combining the results showed that UADs had a statistically significant effect on bat fatalities, with a 50% reduction in overall fatalities.

The species-specific analysis showed that, for some species, fatalities were significantly reduced, e.g. the Brazilian free-tailed bat (54% reduction) and the hoary bat (78% reduction). However, other species did not seem to respond in the same way. Further research is needed to improve species-specific effectiveness. Also, the applicability/accuracy in other parts of the world, e.g. Europe, and to a broader range of species and bat activity data would need to be tested.

Further information is available at the following links or on request from NRG systems[98]:
http://www.batcon.org/our-work/regions/usa-canada/wind2/ultrasonic
https://www.nrgsystems.com/products/bat-deterrent-systems
https://www.nrgsystems.com/news-media/pioneering-bat-deterrent-system-from-nrg-systems-reduces-bat-fatalities-by-54-percent-at-texas-wind-energy-facility/

Acoustic deterrents are included as a potential tool, but concerns about their effectiveness and use remain. They may have uses in specific locations and for certain species, but the research is still at an early stage, and it is not yet clear whether they can sufficiently reduce mortality in real world applications. Furthermore, they may have unintended consequences (such as an initial attraction), which would limit their usefulness. The disturbance effect of such deterrents should also be evaluated.

Other concerns include the need for regular maintenance and testing to ensure there is no gap in deterrence and the ability of any deterrents to adequately protect the entire rotor-swept area in a cost-effective way. As noted in the case study, not all species respond to the deterrents. In addition, effects on other wildlife are not understood for the moment. For all these reasons, further research is required before the use of acoustic deterrents could become a common practice.

[97] http://batsandwind.org/research/operational-mitigation-deterrents
[98] NRG Systems is a designer and manufacturer of smart technologies for a range of wind, solar and meteorological applications

5.4 Birds

5.4.1 Introduction

The potential impacts of wind energy developments on birds have been studied extensively within and beyond the EU. As a result, there are many national guidance documents related to birds and wind energy developments that detail the appropriate methods for collecting baseline data.

Baseline data to support an assessment of significance should be collected using standardised methods (Bissy *et al*; 2000) or national guidance recommendations if those are the best methods available. A comprehensive review of survey methods was published by Smallwood (2017). Examples of baseline surveys are summarised in Box 5-10. In some cases, methods may be combined to accurately describe the baseline conditions. For example, an assessment of pelican collision risk at one wind energy development was based on a combination of radar and direct observations from vantage points (Case Study 5-4).

Box 5-10 Example of onshore baseline surveys for birds

- Vantage point surveys — to identify species, flight behaviour, direction and height.
- Transect surveys — to identify species and distribution and to estimate abundance. These surveys may be generalist and/or focused on specific species or species groups, such as raptors or nocturnal species.
- Indirect counts — bird activity may be measured indirectly, for example by counting droppings.
- Infrared and thermal imagery — to identify nocturnal activity.
- Tracking technology — radio telemetry and satellite tracking data can provide measures of bird activity, flight behaviour, direction and height. These are much more accurate than visual observations (Case Study 5-7).
- Radar — use of radar systems to estimate total bird abundance, flight direction and height, particularly where migratory birds are likely to be present in large numbers. Used in conjunction with visual observation to identify species.

Case Study 5-4 Combining radar and direct observation to estimate the collision risk for pelicans at a proposed wind farm on the Cape West Coast, South Africa

Problem:
The poor location of large-scale wind farms has a detrimental effect on local bird populations and dedicated modelling is therefore required to forecast likely significant effects. Imperfect three-dimensional flight data often result in wrong pre-construction assessments of bird collision risk around wind energy developments. Direct observation data indicated that great white pelicans, *Pelecanus onocrotalus*, regularly flew through the proposed wind energy-development area, potentially within the height of the rotor sweep. A preliminary risk model based on initial observations found a significant collision risk for great white pelicans.

Approach and conclusions:
Radar- and observer-based methods were used to quantify great white pelican flights in the vicinity of a planned wind farm on the Cape West Coast, South Africa, and the turbine collision risk was modelled under various scenarios. Model outputs were combined with pre-existing demographic data to evaluate the possible influence of the wind farm on the pelican population, and to examine mitigation options. High volumes of great white pelican movement through the wind-farm area were recorded, coincident with the breeding cycle of the nearby colony and associated with flights to feeding areas located about 50 km away. Pelicans were exposed to collision risk at a mean rate of 2.02 High Risk flights.h-1 (Jenkins, 2018). Pelican tracks were labelled as high-risk flights if they included points located within the buffered rotor sweep (BRS) of any planned turbine/s. Risk was confined to daylight hours, and was highest during the middle of the day and in conditions of strong north-westerly winds, and 82% of high-risk flights were focused on only five of the proposed 35 turbine placements. Predicted mean mortality rates (22 fatalities per year, 95% confidence, with average bird and blade speeds and 95% avoidance rates) were not sustainable, resulting in a negative population growth rate of the pelican population. Models suggested that removing the five highest risk turbines from the project, or putting in place a curtailment regimen that shuts down at least these turbines at peak traffic times, could theoretically reduce the effects to manageable levels. However, in spite of the large quantities of high-quality data used in the analyses of Jenkins (2018), the collision risk model remains compromised by untested assumptions about pelican avoidance rates and uncertainties about the existing dynamics of the pelican population.

Figure 5-3 shows all great white pelican flight tracks recorded by the radar over the full study period, plotted on a map of the current project layout, with high-risk flights (those intersecting with the BRS) shown in red, and the turbine placements colour-coded according to predicted collision risk. A total of 407 flocks of great white pelicans were tracked through the proposed wind energy development, a total of 4539 birds. Approximately 80% of pelicans passed directly through the wind energy-development site. Radar usage hugely increased the spatial resolution of these data, and allowed more rigorous statistical interrogation as a result. The data can be considered far more accurate and are presented with much greater confidence than observational data alone.

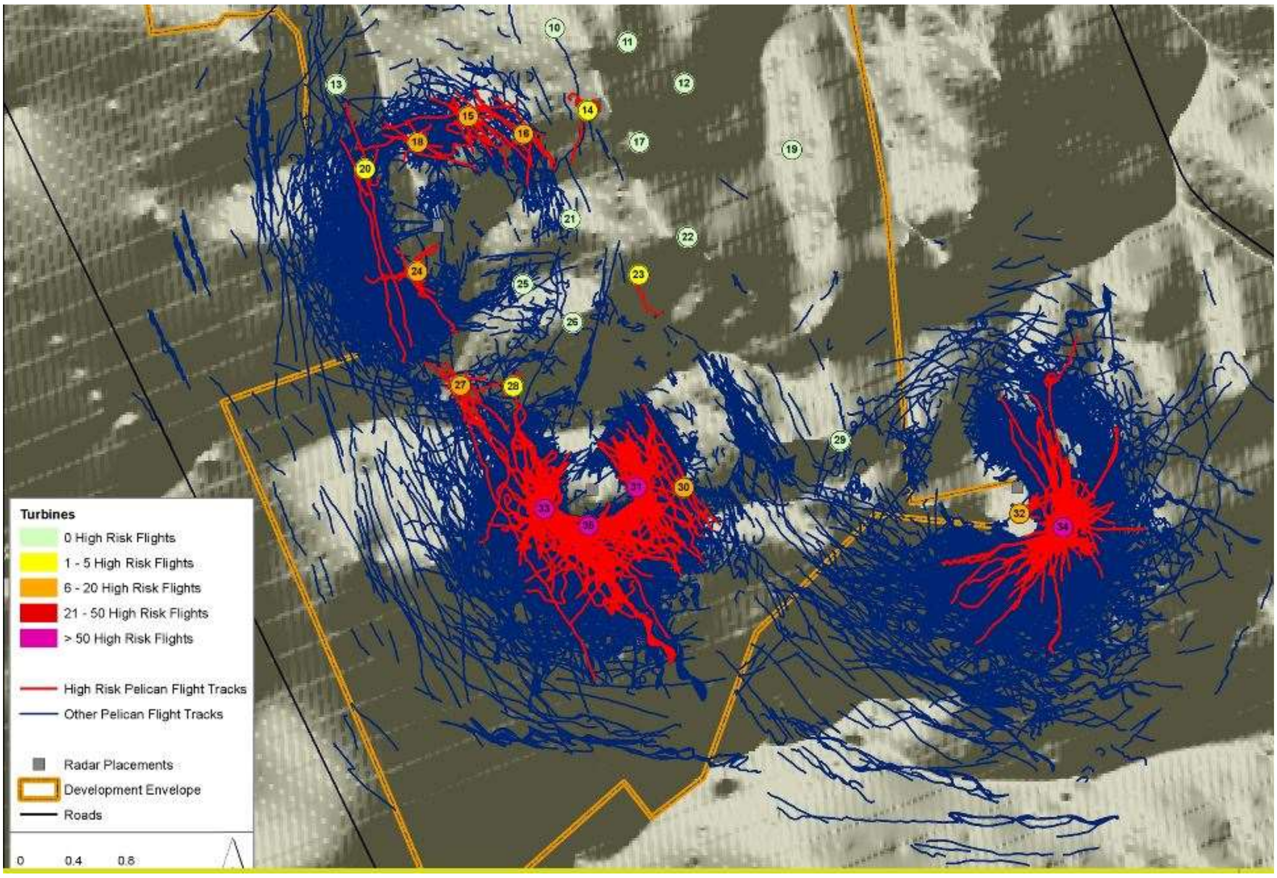

Figure 5-3 Pelican flight tracks recorded by the radar over the full study period

Source: Jenkins *et al*. (2018)

5.4.2 Types of impacts

5.4.2.1 What are the main impact types?

The impacts of wind energy developments on birds have been extensively reviewed (Langston & Pullen, 2003; Perrow, 2017) and are summarised in Box 5-11. The relationship between these impacts and the project lifecycle is highlighted in Table 5-8. Each of impact type has the potential to influence survival rates and reproductive success of individuals, which can result in changes in the demographic parameters of a population, the outcome of which may be a measurable change in population size.

Box 5-11 Types of impacts on birds typically considered in an assessment for a wind energy plan or project

- Collision: the fatal interaction between birds in flight and wind turbine structures.
- Disturbance and displacement: changes in the behaviour of birds can effectively result in the loss of habitat and potentially lower breeding success (Dahl *et al*., 2012), but there are few studies that assess whether there is an effect on the population. Displacement may be measurable within 200 m of turbines but can extend to over 800 m for some species (Hötker 2017; Marques *et al*., 2019). For small-sized and isolated turbines displacement effects may be less likely to occur (Minderman *et al*., 2012).
- Barrier effect: an impenetrable area resulting in additional flight distances to circumnavigate and increased energy expenditure.

- Habitat loss and degradation: the removal, fragmentation or damage to support that habitat birds would otherwise use. There is evidence that such habitat loss and degradation can lead to measurable changes in the population (Pearce-Higgins *et al*. 2012, Steinborn *et al*. 2011).
- Indirect effects: for example, changes in prey abundance and availability may be direct, or mediated via changes in habitats. This may be positive (Lindeboom *et al*., 2011) or negative (Harwood *et al*., 2017) but there is limited evidence of the effect on the bird population. Wind turbine casualties may attract other bird species (scavengers, birds of prey).

Table 5-8: The relationship between types of impacts on birds and the project lifecycle for onshore wind energy developments.

Types of impacts	Project phase				
	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss and degradation		X	X	X	X
Disturbance and displacement	X	X	X	X	X
Habitat fragmentation		X	X	X	
Collision			X	X	
Barrier effect		X	X	X	
Indirect effects	X	X	X	X	X

5.4.2.2 How is significance assessed?

The likely significant effects of wind energy developments on birds are typically assessed in a two-step process involving the quantification of magnitude in terms of bird mortality, followed by an assessment of the change on the population with reference to the conservation objectives of the site in question.

Biological, environmental and plan- or project design factors can influence the significance of effects. Factors typically taken into account in both the design of baseline data collection methods and the assessment of significance in relation to wind energy developments and birds are summarised in Box 5-12.

Box 5-12: Factors determining baseline data collection and the assessment of significance

All effects

- Long-lived, slow-turnover k-selected species, such as large raptors and seabirds, are more vulnerable compared to small, short-lived r-selected species, such as passerines.
- Small and threatened populations (e.g. Annex I species) are more vulnerable to additional sources of mortality than large populations that are stable or growing.
- As a corollary, the proximity of special protection areas – designated because of the presence of these species – is an important impact factor (Marx, 2018).

Collision

- Bird morphology (e.g. body size, wing size and shape) and behaviour (e.g. soaring flight)[99].
- Abundance and seasonality, for example where large numbers of species congregate, such as wetlands and migration bottlenecks.
- Movements: resident birds are at greater risk than those actively migrating.
- Avoidance behaviour and behaviour resulting in prolonged proximity to turbines.

[99] As an example, vultures are typically soaring raptors with their eyes positioned on the area below them in order to scan the area for carcasses; they don't look around them and are therefore very vulnerable to collisions.

- Flight speed (which obviously affects collision risk).
- Flight height (risk of encountering blades).
- Nocturnal flight activity (increased risk at night).
- Flights during adverse weather conditions (increased risk during fog).
- Turbine size (often related to capacity (MW)), wind turbine rotor diameter (swept area – risk zone), placement and wind energy-development configuration (Thaxter *et al*., 2017).
- Infrastructure lighting.
- Topography, for example high elevation sites and the leeward side of ridges relative to the prevailing wind (de Lucas & Perrow, 2017).

Disturbance and displacement

- Turbine height and wind turbine rotor diameter (swept area – risk zone).
- Topography and landscape openness.
- Sensitivity to disturbance varies considerably between but also within taxonomic groups. For instance, some raptors are particularly sensitive while others much less so. It is also possible that some nocturnally migrating passerines are particularly sensitive (also to collision).
- Seasonality: for onshore wind energy developments, greater wind-farm avoidance is seen during the non-breeding season (Villegas-Patraca *et al*. 2012, Hötker 2017).

Barrier effect

- Seasonality: the increased cost of repeated diversions around a wind energy development made by breeding birds moving between their nests and foraging areas may be more substantial than the energetic costs associated with the barrier effect of migrating birds diverting around a wind energy development.
- Cumulative plan and/or project effects: it is unlikely that a single wind energy development would result in significant additional energetic costs to birds as a result of a barrier effect.

Habitat loss and degradation

- How flexible a species is in its habitat use, and the extent to which it can respond to changes in habitat conditions.
- The size and complexity of the plan or project footprint.

Indirect effects

- The sensitivity and vulnerability of habitats and prey species to wind energy-development activities.

An example of how a significance threshold is applied, and at which spatial scale, is illustrated in Case Study 5-5 for the region of Flanders (Belgium).

A more robust approach to determining significance is the use of mathematical models to estimate mortality as well as predict population scale changes over time. However, modelling is more difficult to apply at the level of individual projects. Moreover, careful interpretation is always required in modelling, as models are a simplification of reality. It is recommended to validate models by measuring actual effects in the field.

The approaches often used to estimate bird mortality and determine significance are reviewed in Laranjeiro *et al*. (2018) and summarised in Table 5-9. More than two approaches may be combined to inform the assessment, for example a collision risk model (CRM) may be used to estimate bird mortality, which may then be subjected to a population viability analysis (PVA) to assess the potential consequences of the additional mortality on the population. There is no reason why other approaches not listed below cannot also be used, as long as they have a logical or empirical basis.

Of the likely significant effects on birds, typically only habitat loss and degradation, collision mortality and displacement and disturbance are assessed in great detail.

The assessment of habitat loss is based on the area lost or degraded (see Chapter 5.2). The significance of habitat loss, either through direct loss or indirectly through disturbance and displacement can be informed by scoring the species' flexibility in habitat use (or habitat specialisation) as an initial indication of the likelihood that mortality will occur as a result.

In order to quantify bird collision risk, CRMs[100] are used and parametrised with technical specifications of the turbines, bird morphology and variables describing bird flight activity. The CRM, e.g. the band model (Band 2007 & 2012), provides an estimate of the potential number of bird collisions likely to occur at a proposed wind farm, assuming that birds take no action to avoid colliding with the wind turbines. In order to obtain realistic risk estimates, the collision risk modelling is subsequently corrected to take account of birds' behavioural responses to the presence of wind farms using avoidance rates. However, in practice these also incorporate error and variability in relation to both the data used and the model itself (Cook *et al*., 2014) rather than simply avoidance behaviour per se.

Although there are few instances of empirically derived avoidance rates (Perrow, 2017), there is considerable ongoing debate on how to apply empirically derived avoidance rates into the band model. Discrepancies between modelled predictions and observed collision rates (de Lucas *et al*. 2008, Ferrer *et al*. 2011) highlight the need for caution in interpreting the outputs of CRM and the need to incorporate biologically realistic parameters of bird behaviour into collision risk models.

Barrier effects are known to occur (Hötker, 2017) and must be considered in any assessment of significant effects. There is, however, little evidence of measurable effects, though in some cumulative scenarios this could result in population scale effects (Masden *et al*., 2009).

Table 5-9: Approaches used in the assessment of bird mortality[101]

Approach	Habitat loss and degradation	Collision	Disturbance and displacement	Barrier effect
Collision risk models (CRMs)		X		
Species distribution models (SDMs)		X		
Individual-based models (IBMs)		X	X	X
Population-based models	X	X	X	X
Index-based models[102]	X	X	X	X

Case Study 5-5: Significance assessment approach in relation to birds and wind energy in Flanders (Belgium)

Annual mortality is the current estimated mortality from natural and anthropogenic causes (without the additional mortality linked to planned wind farms or power lines) and is normally calculated based on mortality rates reported in literature (e.g. bird facts on the BTO[103] website) and information on regional/local population sizes of the assessed species.

To determine a potentially significant effect of mortality on species populations, the criterion of 1% of annual mortality is applied for species that may actually be affected, if:

- the species has a local (subregional) population that is significant on the level of the Flanders region (i.e. > 2% of the total regional population), and
- there is enough quantitative data about the population size of the species.

For abundant species with a favourable conservation status, the threshold can be a maximum of 5%.

These thresholds are applied at subregional scale, which for Flanders means the following:

[100] See review of model types by Willmott *et al*. (2012), Grünkorn *et al*. 2016, Masden and Cook (2016) and Smales (2017).
[101] See review by Laranjeiro *et al*. (2018) for specific examples.
[102] Potentially useful when data is scarce (Laranjeiro *et al*., 2018) in order to inform a risk-based assessment.
[103] British Trust for Ornithology, see https://www.bto.org/understanding-birds/birdfacts

- For wintering waterfowl and gulls, unless reliable data are available at regional scale, cumulative effect is assessed at sub-regional scale, and more specifically at the level of subpopulations; these subpopulations at sub-regional (local) scale have been identified based on 'ecologically connected areas' (see Figure 5-4).
- For breeding birds, cumulative effects are also assessed at sub-regional scale, or if needed at local scale (i.e. Natura 2000 site).
- For migrating birds, cumulative effects are assessed at sub-regional flyway scale (estimated population that migrates within this flyway).

Exceptions include cases where not enough data are available to quantitatively assess the effects, i.e. for some bird species and almost all bat species. A more qualitative assessment is made in these cases, if possible also based on (available) quantitative data, as well as expert judgment. Other exceptions include cases where a detailed population effect model is used with a different outcome, but so far this hasn't been applied in Flanders.

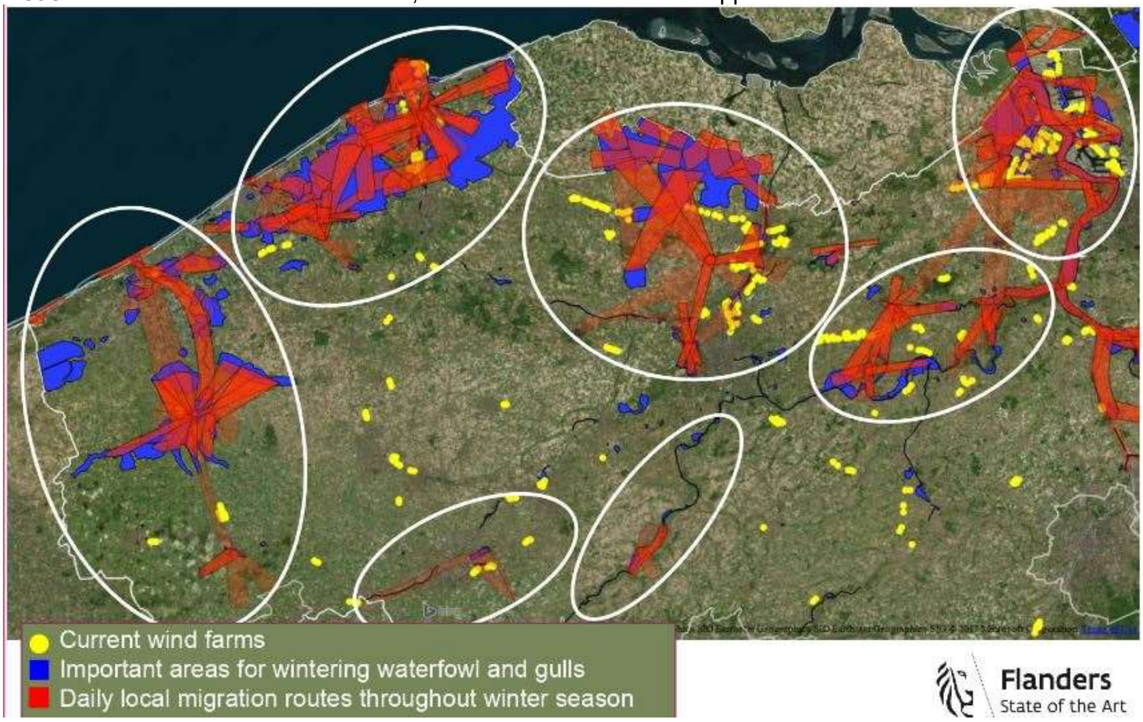

Figure 5-4: Identified subpopulations of wintering waterfowl and gulls at sub-regional (local) scale in Flanders

Source: Everaert, J. (2017)

The use of population-based models in the assessment of significant effects has been reviewed in Green *et al*. (2016), O'Brien *et al*., (2017) and Smales (2017). The use of population viability analysis (PVA) is increasing because the 'with' and 'without' plan or project scenarios allows for an assessment that is both in line with international best practice principles on impact assessment (Brownlie & Treweek, 2018) and with the need to consider the population maintenance or restoration objective of the Birds Directive. For example, Jenkins *et al*. (2018) used a Leslie matrix population model, the basis of PVA, to assess the population consequences of collision mortality on a breeding population of pelican. PVA models require population and demographic values to be obtained from long-term datasets for the species being investigated. Where such data are not available, other models such as potential biological removal (PBR) may be appropriate (Smales, 2017). Alternatively, integrated population modelling (IPM) could be used to estimate demographic parameters from other sources of data, including survey data, and these inferred parameters may be used in PVA (Smales, 2017). A detailed review of IPM is provided in Schaub and Abadi (2011).

Monitoring is essential to ensure that the scientific basis underpinning the conclusions of an assessment remain valid in the long term. The need for, and general approaches to, monitoring are discussed in Chapter 6. For birds, the focus of monitoring is typically on collision risk and understanding if CRM predictions hold true in reality. To do this, it is necessary to search for and identify carcasses from wind turbine collisions and then estimate the total number of collisions. A review of the statistical analysis principles applied to estimating collision mortality from carcass searches is given in Huso *et al*., (2017). Statistical bias as a result of differences between the searchable area and the total area in which a carcass could fall, searcher efficiency and scavenger rate, must be accounted for in any estimate of collision mortality. Methodological guidance on conducting carcass searches is given in national guidance (see, for example, Atienza *et al*., 2014 for Spain). Software tools to estimate collision mortality from the carcass search survey data are available from a number of sources, for example the R-package carcass (Korner-Nievergelt *et al*., 2015) and GenEst (Generalized Estimator) (Simonis *et al*., 2018). A summary of GenEst is given in Case Study 5-6.

Case Study 5-6: GenEst, A tool for evaluating collision mortality at wind energy developments

Problem:
Quantifying collision risk using corpse recovery techniques is difficult in terms of both time and space and, therefore, some degree of statistical modelling is required to fully understand the risk to bats and birds posed by wind energy-development infrastructure. However, these approaches often vary as to the factors they consider and therefore data between sites are scarcely comparable.

Solution:
GenEst is a generalised estimator of mortality, which computes the number of bird and bat fatalities at wind-farm sites where detection is imperfect. The software is available in the statistical package 'R' or as a graphical user interface (GUI) and therefore enables ease of access for those who may not have experience in statistics, complex mathematics or computer programming.
Practical/technical considerations:
Carcass collection data at a wind energy development is imperfect and accurate representation is dependent on a series of fine-scale factors (such as predation rate, climate, and body mass of the casualty). This approach does require a small amount of training prior to effective usage, either through the GUI or in the base R programming syntax, however, the learning curve is greatly reduced compared to manual model computation.

Advantages:
The GenEst software is available in R or as a GUI and therefore enables ease of access for those who may not have experience in statistics, complex mathematics or computer programming. As is standard for all R packages, guidance notes are stored and freely available on the Comprehensive R Archive Network (CRAN) (Dalthorp *et al*., 2019). Open-source software and model design (Dalthorp *et al*., 2018) mean that results are comparable between projects which have used the same tool, and are as a consequence, better informed.

Source:
Dalthorp, 2019 & Dalthorp, 2018.

Case Study 5-7: Identification of displacement effects on the Golden Eagle (*Aquila chrysaetos*) through GPS tracking in France

The French Massif Central hosts a small population of Golden Eagle that could be potentially affected by the development of wind farms. A study was conducted in order to assess the reliability of the methods commonly applied in impact assessments and to develop new ones. This study also aimed to improve knowledge about these effects. To achieve these objectives, two Golden Eagles that were part of the population of the species in the area were equipped with GPS tracking devices during the 2014–2015 period (baseline) and in 2016–2017 (after construction of the wind farms). The study showed that, contrary to the conclusions made in the impact assessments, the species no longer used a large part of the habitat after the two wind farms were built in the core area of their hunting habitat (Figure 5-5).

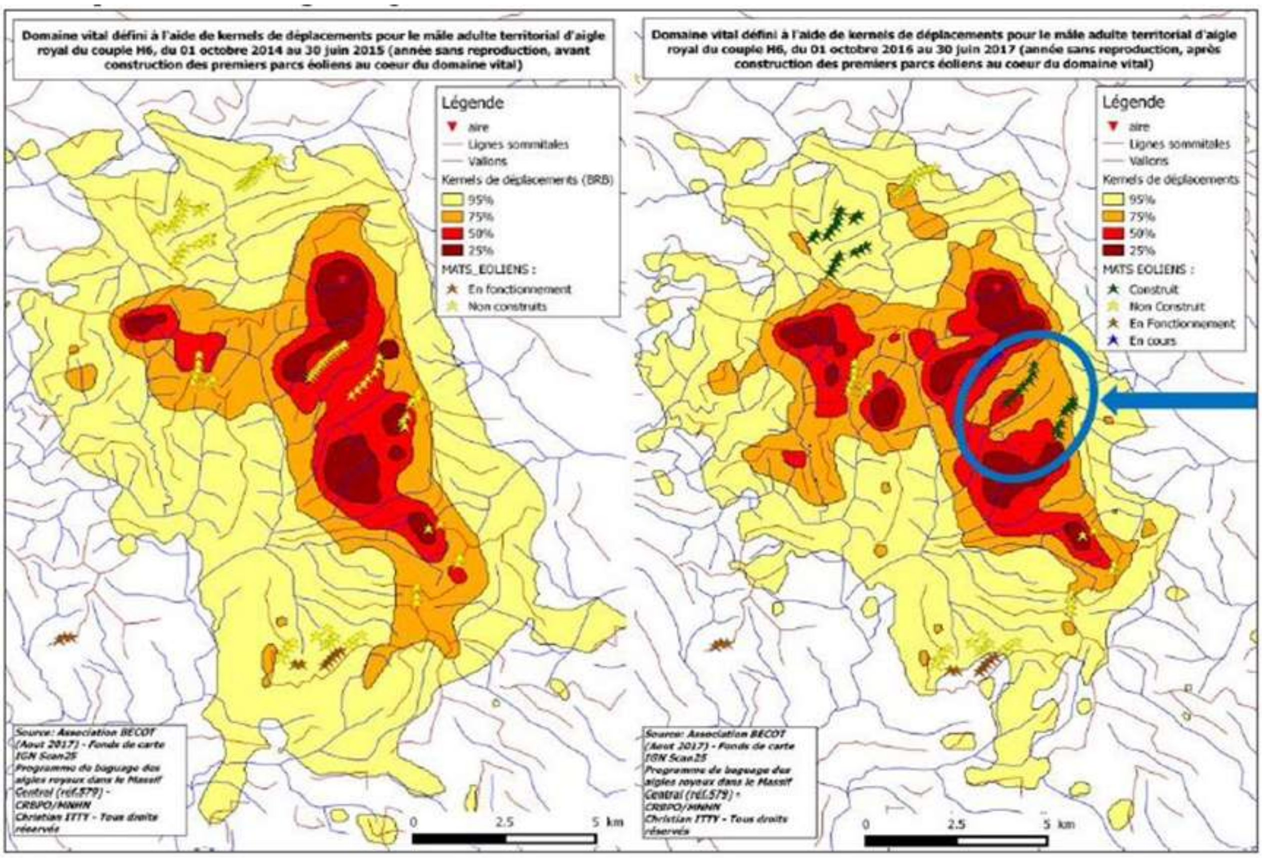

Figure 5-5: Displacement effects on the Golden Eagle due to the construction of wind farms in the French Massif Central (the left figure shows the situation in 2015, when the two wind farms had not yet been built in the middle of the eagles' territory; the right figure shows the situation in 2016, after the two wind farms had been constructed)

The study also confirms the sensitivity of the Golden Eagle to collision risk related to wind turbines. Although caution is required when generalising the study's findings, which are based on the GPS monitoring of a single couple, this case shows the significant effects of three wind farms in the eagle's territory on the way the eagles select their preferred routes and hunting areas. The presence of the wind farms reduces their habitat (+/- 450 ha less habitat) and affects their movement from one area to another.

Source: Itty (2018)

Uncertainties and challenges which were encountered in the assessment of likely significant effects on birds, and which may require additional baseline data collection or the application of the precautionary principle, are summarised in Box 5-13.

Box 5-13: Key challenges in assessing the significance of effects on birds

Collision

- Knowledge of factors associated with collision risk, for example foraging and territorial behaviour and wind and topography interaction, is typically site-specific and based only on relatively common species (Watson *et al*., 2018).
- Abundance and seasonality, for example in areas where large numbers of sensitive species congregate such as on wetlands and in cases of migration bottleneck, with high population density or habitat suitability (Heuck *et al*. 2019).

Disturbance and displacement

- The measurable change in a species population often differs between project sites.
- There is limited empirical data supporting index-based model predictions. See Case Study 5-7 with empirical evidence based on GPS tracking techniques.

Barrier effect

- Empirical data is limited because previous studies have applied inappropriate methodologies, have not differentiated barrier effects from displacement effects and because of the limitations of radar techniques, for example in species identification.
- There is limited empirical data on breeding birds because previous studies have focused on migratory birds.
- The cumulative barrier effect on long-distance migrants of avoiding multiple arrays along the course of their migration route remains unstudied.

Habitat loss and degradation

- There is limited empirical data supporting threat identification or index-based model predictions.

Indirect effects

- There is limited empirical data regarding the sensitivity and vulnerability of prey species and the importance in terms of survival and reproductive success to the bird species in question.

A number of key recommendations for the assessment of likely significant effects on birds are summarised in Box 5-14.

Box 5-14: Key recommendations for assessing the significance of effects on birds

- Define clear significance criteria which refer to the conservation objectives for the birds concerned, and which are context-specific (case-by-case) and scientifically underpinned.
- Ensure availability of data, notably in relation to bird mortality and subsequent effects on populations at an appropriate scale to inform plan-level assessments and detailed project-specific survey and assessment.
- Invest in research in order to fill the knowledge gaps listed in Box 5-13.
- Benefit from the increased availability of post-development monitoring reports to improve the evidence base.

5.4.3 Possible mitigation measures

5.4.3.1 Introduction

The following sections provide an overview of possible mitigation measures that are proposed or applied to minimise the effects of onshore wind energy developments on birds. The limitations of these measures should be taken into account, especially when wind turbines are installed on sites with high avifauna value and where there is a substantial level of uncertainty as to whether some of the measures listed will be effective. The appropriate siting of wind farms and their associated infrastructure (macro-siting) is the most obvious mitigation measure to avoid any negative impacts on birds and wildlife in general.

5.4.3.2 Micro-siting: Turbine arrangement and position

Micro-siting turbines aims to avoid or reduce collision risk, displacement and barrier effects.

Informed by baseline field survey data or operational monitoring data, micro-siting is the process by which individual turbines are placed in areas suitable for low-ecological-risk deployment. Geographic information system (GIS) approaches[104] are often used to inform micro-siting decisions, either by mapping, for example, bird habitat utilisation and movements or by mapping atmospheric and topographic features, such as thermals and orographic up draughts, which are known to affect collision risk.

Several studies have shown an uneven distribution of collision risk among wind farms, with a small number of turbines having a disproportional effect (see also Case Study 5-5). Turbines associated with certain geographical features, such as ridgelines, are likely to have a greater effect. However, the effect of turbine configuration is likely to be very site- and species specific. Migratory birds are likely to benefit from increased spacing between turbines, which creates flight corridors, or from placing turbines in separate discrete clusters

[104] See for example: Innovative mitigation tools for avian conflicts with wind turbines (INTACT) (https://www.nina.no/english/Research/Projects/INTACT)

(May, 2017). The effectiveness of micro-siting is not currently supported by empirical evidence, but is supported by predictive modelling (Arnett and May, 2016).

5.4.3.3 Infrastructure design: Turbine number and technical specifications (including lighting)

Infrastructure design aims to reduce collision risk but may also influence displacement and barrier effects.

Using baseline field survey data or operational monitoring data with predictive modelling, such as collision risk models (CRMs), the influence of turbine number and design can be explored in order to establish a final design that can be considered to be ecologically low-risk.

Generally, fewer and larger turbines, placed further apart, may be preferable to many, densely packed small turbines (May, 2017). The effectiveness of turbine design is supported by some empirical evidence (e.g. Loss *et al*., 2013) but the influence of increasing rotor diameter (collision risk window) and reducing rotor speed may only reduce collision risk at an intermediate combination. Although such design (i.e. fewer and larger turbines) may reduce collision risk for most local species, there might be an increased risk for species flying at higher altitudes, for instance during seasonal migration. This still needs to be supported by evidence.

Wind turbine lighting does not seem to increase the collision risk for bats or migrating songbirds[105].

As regards the disturbance of breeding birds, with everything else being equal, taller turbines have a smaller impact on breeding birds. Turbines with longer blades have a larger negative impact (Miao *et al*. 2019).

5.4.3.4 Scheduling: Avoiding, reducing or phasing activities during ecologically sensitive periods

Scheduling aims to avoid or reduce the disturbance and displacement of birds during certain critical periods. It may be of most use during construction, repowering and decommissioning, rather than during operation. Scheduling means that activities are either suspended or reduced during ecologically sensitive periods. Another option is to phase the activities, so that they continue but only at less sensitive locations. This can be done by using existing ecological knowledge of the species likely to be present at the wind energy development, baseline field survey data or operational monitoring data.

It is common practice to undertake potentially disturbing activities during periods where sensitive and vulnerable species are absent, e.g. by avoiding aggregations of water birds in winter when the energetic cost of disturbance is highest or by avoiding the breeding season when the risk of damaging, destroying or disturbing an active nest is high.

5.4.3.5 Disturbance reduction: Alternative construction methods and barriers

The use of alternative construction methods and barriers aims to avoid or reduce disturbance and displacement. In principle, such measures are likely to be effective when implemented, although there is limited published evidence of this.

Any measure that avoids or reduces a noise or visual stimuli that is known to or is likely to cause a change in the behaviour of bird species should be considered. This includes measures that can reduce the noise output of the potentially disturbing activity, reduce the noise received by the sensitive receptor or block visual stimuli such as the presence of people.

The effectiveness of alternative construction methods needs to be considered on a case-by-case basis, and should be supported by predictive noise modelling. For example, the use of percussive piling may cause disturbance to birds, but the use of a non-metallic 'dolly' between the hammer and the driving helmet (The British Standards Institute, 2013) may reduce the noise levels sufficiently at the receptor and therefore avoid or reduce a likely significant effect. Other methods may avoid percussive, startling noise by using vibration to drive or screw piles (continuous flight augur) into the ground.

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[105] https://awwi.org/wind-turbine-impacts-on-birds-and-bats-2016-summary-now-available/

The effectiveness of acoustic barriers is dependent on barrier material, location, dimension and shape. The barrier should reduce the noise levels behind it, a 'shadow zone'. It needs to be high and long enough to maximise the shadow zone so that it encompasses the area occupied by the receptor. The closer the barrier is to the source of the noise, the smaller it needs to be. Material such as mineral wool, wood fibre, fibre glass and concrete with holes or a mixture of different materials can improve a barrier's noise attenuation performance (Pigasse & Kragh, 2011). The assessment of the effectiveness of acoustic barriers must be supported by predictive noise modelling.

Placing screens to block the presence of people as well as noise from ecologically sensitive areas has also been applied, particularly in relation to water birds, and is considered to be effective (Cutts *et al*., 2009).

5.4.3.6 Curtailment: Timing of turbine operation

Despite the fact that stopping wind turbines does not prevent night collisions during migration (mainly of passerines), temporary curtailment could be effective in avoiding or reducing the collision risk, especially during ecologically sensitive periods.

Many proposed measures focus on adjusting wind-farm operation, for example by temporarily shutting down turbines when birds are in close proximity. Temporary 'shutdown on demand' has been introduced at a small number of wind farms (see Case Study 5-8 and Case Study 5-9). Technicians use a combination of human observers, avian radar (Tome *et al*. 2011, 2017) and occasionally video (Collier *et al*. 2011) to anticipate potential collisions and then temporarily turn off the turbines. In some cases, a video-based detection system called DtBird®[106] is used. DTBird® is a self-working system for bird monitoring and/or mortality mitigation at on- and offshore wind turbine sites. The system automatically detects birds and can take two independent actions to mitigate bird collision risk: activate warning sounds and/or stop the wind turbine.

Shutdown on demand can work effectively and with minimal loss of total energy production. However, it relies on skilled, conscientious technicians and can therefore be difficult to sustain and costly to finance in the long term. Shutdown on demand is most effective (and affordable) when it is only required over a limited and predictable time period, for instance during specific periods in the breeding or migration season (e.g. peak migration days). As a precautionary measure, it is good practice to include some level of curtailment in the cost model for a wind energy development so that both the financial and biodiversity risks are recognised whilst maintaining an economically viable project. The effectiveness of a shutdown on demand protocol applied year-round is unknown and likely to be both more difficult to coordinate, and less likely to be economically viable. Sites operating shutdown on demand should have robust monitoring protocols in order to ensure that collisions are indeed being prevented.

'Shutdown on demand' is usually applied to a set of species identified as being at an increased risk, or where the species' conservation status is of concern. It is rarely designed to prevent all avian collisions. It is important to agree on this set of species in collaboration with qualified and experienced ecologists.

Given these conditions and limitations, there is no general consensus yet that this measure is effective. In Germany, such measures are applied only in single cases (as tests). They are not seen as normal or good practice methods yet. More research and development of the avian radar and video-based detection systems are needed to improve efficiency, practicability and reliability. Currently, the systems don´t have sufficient command of practicability (e.g. detecting target species with low error rate)[107]. Recent research (Everaert, 2018) concludes that the available information sources used to predict the intensity of bird migration are useful for improving the safety of the military air force, but not sufficiently reliable for managing 'shutdown on demand' of wind turbines during bird migration. This might improve in the future with the development of better and more local prediction models supported by meteorological and local bird radars. As illustrated in Case Study 5-8 and Case Study 5-9, 'shutdown on demand' measures still seem to require additional human observers.

Another application of the 'shutdown on demand' measure is illustrated in Case Study 5-10, It relates to particular farming activities that may attract raptors in the vicinity of wind farms.

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[106] https://dtbird.com/images/pdfs/Brochure-DTBird.-March-2019.pdf
[107] See also https://www.naturschutz-energiewende.de/aktuelles/vogelschutz-an-windenergieanlagen-kne-fachkonferenz-war-ein-voller-erfolg/

Given their potential consequences for the economic viability of a wind energy project, such 'shutdown on demand' measures could be seen as a last resort option, to be implemented after all other alternatives have been explored.

Case Study 5-8: Observer-assisted shutdown on demand (Tarifa, Spain)

From 2008 to 2009, 10 wind farms consisting of a total of 244 turbines were subject to daily surveillance to document griffon vulture *Gyps fulvus* collision mortality. When a vulture was observed flying in a trajectory that could potentially result in a collision with turbine blades, or when a group of vultures flew within or near a wind farm, the observer would contact the wind-farm control office to switch off the specific turbines involved. The turbine could be brought to a halt within a maximum time frame of three minutes.

There were 4,408 turbine stops, and the shutdown on demand measure reduced griffon vulture mortality by 50%, with drop-in energy production at only 0.7%. On average, the shutdown was implemented for a total of six hours and 20 minutes per turbine per year, with the mean duration of a stop being just over 22 minutes.

Source: de Lucas *et al*. (2012)

Case Study 5-9: Radar-assisted shutdown on demand, Barão de São João Wind Farm, Portugal

The 50 MW Barao Sao Joao Wind Farm of E.ON[108], located on a migratory flyway, applied a radar-assisted shutdown on demand (RASOD) protocol based on a pre-defined set of criteria.

A monitoring team conducting vantage point watches was used to monitor migratory bird flight activity. Real-time radar data provided the monitoring team coordinator with better quality information based on which to initiate a shutdown. Over time, the monitoring team's experience positively influenced the effectiveness of the RASOD approach: the average time it took for a shutdown to happen after an order was given decreased by 91% and the average annual equivalent shutdown hours decreased by 86% over the 2010–2014 period.

Turbine blades could be immobilised within approximately 15 seconds of a shutdown being initiated, using a 'supervisory control and data acquisition' (SCADA) system to provide real-time access to and management of individual wind turbines and wind farms. Additionally, turbines were restarted again without the need for additional communication with operational staff.

No collisions of migratory soaring birds were recorded during the application of the shutdown protocol. By the final year of the five-year study, the total equivalent shutdown period corresponded to 0.2% of the annual available equivalent time, and more than 40% of the equivalent shutdown periods resulted in negligible energy losses by virtue of low wind speeds.

Source: Tomé, 2017.

Case Study 5-10: Shutdown during crop harvesting, Germany

An operational shut down of wind turbines can be useful when farmers are harvesting their crops or ploughing underneath. This is because – depending on the area and on the raptor species – more raptors hunt in an area during and after harvesting due to the increased exposure of worms and other small (dead) animals (e.g. mice).

However, experience has shown that, from a logistical point of view, implementing this measure is quite complicated. It requires a pro-active attitude from farmers to inform the site operator of their farming activities, and this is not always the case.

[108] E.ON is a European electric utility company based in Essen, Germany

Source: Workshop on the impacts of onshore wind and solar energy on species and habitats protected under the Bird and Habitat Directives, held in Darmstadt, Germany on 14 December 2018 (Source: Ubbo Mammen - https://www.natur-und-erneuerbare.de/projektdatenbank/projekte/wirksamkeit-von-lenkungsmassnahmen-fuer-den-rotmilan/

5.4.3.7 Acoustic and visual deterrents

The use of deterrents aims to reduce the risk of collision. Evidence of the effectiveness of such techniques remains limited, and it is likely that their effectiveness is highly site- and species specific.

Deterrents typically involve the installation of devices that emit audible or visual stimuli either constantly, intermittently or when triggered by a bird detection system (e.g. DtBird®, see Chapter 5.4.3.6). Passive deterrents such as painting can also be applied to turbine towers and blades, although they are not allowed everywhere in the EU. In France, for instance, wind turbines must be uniformly white or light grey.

Visual and audible signals have been tested as a way of alerting birds to turbines or to scare them away. Measures have included painting rotor blades to make them more visible, using pulsating lights to deter nocturnal migrants, and installing auditory deterrents such as alarm and distress calls and low-frequency infrasound. Most recently, researchers in France have tested a visual pattern that creates an optical illusion evoking ‘looming’ eyes to keep raptors away from an airport runway. They suggest that the technique could work for wind farms but this has not been tested yet (Hausberger *et al*. 2018).

Case Study 5-11: Increased visibility of painted of turbine blades and towers at Smøla wind farm, Norway

A research project in Norway (2014) with four turbines at Smøla wind farm had one rotor blade painted black in an effort to see whether mortality could be reduced by increasing the blade's visibility for birds. In addition, the bases of ten turbines were painted black up to 10 m above ground during the summers of 2014 and 2015. The research results are yet unpublished, but first indications revealed that the mortality of Willow Ptarmigan (*Lagopus lagopus*), the species most frequently found dead under the turbines, seems to have been reduced following these visual modifications. Research is still ongoing.

Source:
- Raptor Interactions With Wind Energy: Case Studies From Around the World Authors: Watson, 2018
- Photo: Espen Lie Dahl

Case Study 5-12: Use of an automatic collision avoidance system to reduce the collision impact on pelicans (*Pelecanus crispus* and *Pelecanus onocrotalus*) at Prespa Park, Greece

A wind farm of ca. 29 MW is located next to the Prespa Lake in Greece, an area that includes two Nature 2000 sites, as well as Ramsar wetland.

Due to the presence of 20% of the global population of Dalmatian pelican (*Pelecanus crispus*) and Great white pelican (*Pelecanus onocrotalus*) in the broader area, and especially due to the fact that the pelicans use the wind-farm sites as one of their frequent passages to other wetlands, an automatic collision avoidance system for birds was installed in 2013. The system uses high accuracy cameras to identify the pelicans that fly into the area, and in the case of birds flying inside the collision risk area, activates warning sounds to deter the pelicans and/or temporarily shuts down the wind turbines.

No collisions were detected during the monitoring period and therefore the automated avoidance system was considered to be an effective measure.

Source: WindEurope (2017)

5.4.3.8 Habitat management: luring and dissuading species away from turbines

Habitat management measures aim to reduce the collision risk. They have typically included the application of a management regime (location and timing) to reduce prey availability, as well as habitat creation or enhancement to lure birds away from turbines. The provision of supplementary food is also considered an effective measure.

Such measures, reviewed by Gartman *et al*. (2016), must be considered site-by-site and on a species-specific basis. Habitat management to alter prey abundance and reduce collisions is known to be effective, although this is based on a relatively small number of published cases (see for example Case Study 5-13).

Scottish Natural Heritage (2016) considers that, in most cases, habitat management to lure birds such as the short-eared owl and hen harrier away from turbines should not be relied upon due to the lack of certainty on whether the measures will be effective. The effectiveness and ecological consequences of diversionary feeding must be considered on a case-by-case basis.

Case Study 5-13: Habitat management to reduce collision risk for Lesser kestrel (Falco naumanni), Spain

Operational monitoring was conducted across three wind energy developments (Cerro del Palo, Cerro Calderón and La Muela) consisting of 99 turbines, to determine the variables associated with Lesser kestrel (*Falco naumanni*) collision mortality. Based on the information obtained, a mitigation measure was implemented to avoid and minimise collisions. At turbines with high collision mortality rates, the soil around the base of the turbine was lightly tilled to reduce the amount of vegetation and consequently the abundance of potential prey, mainly Orthoptera. In the two years of habitat management monitoring, no collisions were recorded where the soil had been tilled. The measure is an easy and inexpensive procedure that significantly and effectively reduces Lesser kestrel collision mortality.

Source: Pescador, 2019.

5.5 Other species

5.5.1 Introduction

There has been relatively little research regarding the potential effects of onshore wind energy developments on species other than birds and bats. A comprehensive list of EU-protected species listed in Annexes II, IV and V of the Habitats Directive is given in Annex II of the Commission's guidance on strictly protected species. It is important to recall that the breeding and resting places of species listed in Annex IV of the Habitats Directive are protected from disturbance. Where such disturbance is predicted to occur, the appropriate derogation can be applied if the conditions of its use are met. In assessing the significance of effects, particular attention should be given to direct and indirect changes in the quantity and quality of habitats.

The level of uncertainty is considerably higher as regards the impacts of wind energy developments and associated infrastructure on species other than birds or bats. In instances where the EU-protected species are not birds or bats, it is essential that the likely significant effects are determined based on a comprehensive review of the best available scientific information related to the species or species group concerned.

Where there is uncertainty and in the context of the precautionary principle, the assessment on what will happen to the site if the plan or project goes ahead must be consistent with ‘maintaining or restoring the favourable conservation status’ of the habitat or species concerned[109].

This chapter summarises the current level of understanding regarding the potential effects of onshore wind energy developments on species other than birds and bats.

5.5.2 Types of impacts

5.5.2.1 Mammals

A review of mammals and wind energy-development interactions carried out by the Swedish Environmental Protection Agency (Helldin *et al*., 2012) found little evidence of significant effects. However, significant temporary avoidance by large carnivores and ungulates was reported (Helldin *et al*., 2017). Whilst species that require large expanses of undisturbed habitat are most likely to be at risk of significant effects, effects on species tolerant to disturbance may also occur when conditions in undisturbed habitat patches in the landscape change (Helldin *et al*., 2017).

Other research demonstrated that badgers (*Meles meles*) in the UK experienced increased stress levels caused by wind turbine noise (Agnew, 2016). Hair cortisol levels were used to determine if the badgers were physiologically stressed. The hair of badgers living less than 1 km from a wind farm had a 264% higher cortisol level than that of badgers living more than 10 km from a wind farm. No differences were found between the

[109] C-258/11, Sweetman and Others, ECLI:EU:C:2012:743, [2012] Reports of Cases (Court Reports - general), paragraph 50.

cortisol levels of badgers living near wind farms operational since 2009 and 2012, indicating that the animals do not become habituated to turbine disturbance. Higher cortisol levels in affected badgers may affect their immune systems, which could result in increased risk of infection and disease in the badger population.

Łopucki (2018) didn't observe any adverse impacts on the spatial distribution of European hamster (*Cricetus cricetus*) within wind farms in Poland. Łopucki, R., & Mróz, I. (2016) found no influence of wind energy developments on the diversity and abundance of small mammal species. For larger mammals, Costa *et al*. (2017) recorded displacement of denning locations (shelter) by up to 2.5 km for grey wolf (*Canis lupus*) on wind energy developments in Portugal. The authors also observed lower reproduction rates during construction and the first years of operation.

Łopucki *et al*. (2017) found that both roe deer and brown hare (*Lepus europaeus*) avoided the interior of a wind energy development and that there was a reduction in the frequency of habitat use measurable up to a distance of 700 m. For these species, which rely on hearing to detect predators, this displacement may be a result of their impaired ability to detect predators, especially where there is high predation pressure. Red fox (*Vulpes vulpes*) was observed to visit the interior of a wind energy development less often, possibly as a result of both lower prey availability (brown hare) and an impaired hearing ability when hunting. Red fox are likely to utilise access roads and scavenge the carcasses of birds killed by colliding with operational turbines.

Some considerations concerning the effects on mammals are set out in Box 5-15.

Box 5-15: Considerations concerning impacts on mammals (adapted from Helldin *et al*., 2012)

- Disturbance during construction may be temporary.
- The significance of effects is likely to be dependent on the availability of habitat and existing levels of disturbance within the wider landscape.
- Avoidance of large areas around associated infrastructure such as transmission lines may be observed.
- Displacement of denning locations for larger predators may be observed.
- New access roads may facilitate movement of individuals (but consequently bring them into contact with road traffic).
- Significant effects may be likely to occur in more remote, upland and currently inaccessible areas where improving access for recreation, hunting and leisure is likely to result in increased human presence and traffic.
- Habituation of species cannot be presupposed as it depends on variation between species, sex, age, individual, time of year, type of disturbance, and on how frequent and predictable disturbance is.
- The significance of effects is likely to be in direct proportion to the size of a wind energy development.
- The accumulation of many small effects could be significant at the population-level scale.

5.5.2.2 Amphibians and reptiles

A review of the effects of wind energy developments on reptiles and amphibians (herpetofauna) found little published evidence (Lovich *et al*., 2018). Wind energy-development site operations were found to result in incidental reptile mortality, with displacement from areas with the highest turbine concentration in the long term (Agassiz's desert tortoise *Gopherus agassizii*).

The Common Tortoise (*Testudo graeca*) – classified as vulnerable according to the IUCN Red List – might be affected by habitat loss and fragmentation close to access roads due to wind-farm construction in south-eastern Europe, in particular when wind farms are built in rocky or steppic habitats. See also Case Study 5-1.

Research carried out in Portugal using models and simulations based on empirical data shows that vertebrate species richness (including herpetofauna) decreased by almost 20% after the installation of only two large monopile turbines. Indirect effects may however occur where wind energy developments reduce the abundance of species that prey on herpetofauna, as suggested by the increase in reptile density and changes to their behaviour, physiology and morphology at a wind energy development in India (Thaker *et al*., 2018).

5.5.2.3 Invertebrates, plants and aquatic organisms

Wind energy developments have the potential to have significant effects on these groups, especially through habitat loss, degradation and fragmentation. The information discussed previously in relation to onshore habitats (Chapter 5.2) is also relevant here.

A review by O'Connor (2017) stated that, although effects on aquatic organisms may occur, they can be effectively mitigated. The construction phase of a wind energy development is most likely to result in significant effects, especially where turbines are located within 50 m of aquatic habitats. An assessment of likely significant effects must therefore take into account, as a minimum, changes in the surrounding habitat, changes to hydrology, sediment supply and accumulation, noise and vibration and the presence or potential introduction of invasive non-native species.

It is likely that the most significant effect on invertebrates will be from the loss, degradation and fragmentation of habitats and substrate on which they already live. There is little available empirical data on effects related to insects and other invertebrates. Long *et al*. (2011) observed differences in insect abundance in relation to turbine colour and Foo *et al*. (2017) found that insect communities remained relatively consistent between monitoring years. Whilst the attraction of insects such as Lepidoptera (butterflies and moths) to wind turbines may be problematic in relation to the collision risk of foraging bats, there is currently no evidence that wind energy developments are a threat to insect populations.

The most significant effect on plants comes from the loss, degradation and fragmentation of substrate in which they grow. Annex II and IV protected plants which are not part of Annex 1 protected habitat types are protected by the species protection regime a described under Chapter 2.2.4.

Although some studies have found evidence of changes in microclimate as a result of wind-farm development, no resultant influence on plant reproductive success, physiology or morphology has been reported.

5.5.3 Possible mitigation measures

As noted in relation to habitats, the appropriate siting of wind energy developments through strategic planning is the most effective way to avoid negative effects on species. As a second measure, individual turbine-associated infrastructure should be carefully placed to reduce the magnitude of effects.

To prevent or reduce accidental killing of small mammals, reptiles and amphibians by road transport, restricting access to access roads seems to be a useful measure. Access roads can also be reduced in size as they don't need the same width for maintenance activities.

Habitat management might be another relevant measure for populations of protected species (mammals, reptiles, amphibians, plants).

5.6 Decommissioning and repowering

5.6.1 Decommissioning

Decommissioning is the reverse of construction, whereby all or part of the wind energy development infrastructure is removed, and the land affected is restored to the condition stipulated by the competent national authority. Decommissioning may also be applied to individual turbines or groups of turbines as a measure to reduce ongoing effects, as part of an adaptive management plan (see Chapter 7) or as a result of a review by a competent authority.

Where turbines have not produced electricity on a commercial scale for 12 consecutive months, it is good practice to decommission them, and to restore the site to preconstruction conditions.

For bird and bat species, decommissioning can be an effective measure in reducing collision risk (Gartman *et al*., 2016). Where monitoring identifies that one or more turbines are responsible for an unforeseen but significant effect, a review by the competent national authority should include the possibility of decommissioning or relocating of these turbines.

5.6.2 Repowering

Repowering involves the removal of existing turbines and the construction of new turbines, often of a larger size and capacity. As a result, repowering projects typically use fewer turbines than the original wind energy development, either on existing or new foundations. Reducing the number of turbines has the potential to reduce the displacement effect. Both micro-siting and the influence of infrastructure design can be investigated in order to ensure that the development carries a low ecological risk (see Case study 5-14).

Repowering facilities are often able to generate higher energy yields from lower wind levels. Although this gives the benefit of reducing bird fatalities at wind facilities with historically higher collision rates, it can increase the collision risk for bats due to the larger swept area of the turbine blades (Gartman et al. (2016)). It may also change the economics of curtailment strategies. As such, repowering should be considered on a site- and species-specific basis.

Bat data collected at nacelle height from existing turbines can be used to ascertain the likely mortality risk and to draw up curtailment programmes if required. As replacement turbines are usually built on new foundations, the decision on the new locations should take into account the monitoring data collected during operation.

The effect of applying aviation lighting is also worth considering. As turbine height tends to increase with repowering, more turbines may need to be fitted with turbine lighting. Although the effects of turbine lighting on birds seem to be limited, the light colour may attract bats, leading eventually to an increased collision risk of migratory bats at wind turbines. Case study 5-14 describes how monitoring data were used to model different repowering scenarios and reduce the risks for the white-tailed eagle in Norway. Case study 5-15 describes the repowering of a wind farm in Zeebrugge, Belgium.

Case study 5-14: Reducing the collision risk of the white-tailed eagle (*Haliaeetus albicilla*) by repowering the Smøla Wind farm, Norway

The white-tailed eagle, *Haliaeetus albicilla,* has been identified as the most vulnerable species to operational turbines at the existing Smøla wind farm, due to increased disturbance and due to increased mortality from collisions with turbines. Monitoring was carried out at the operational wind farm (68 2-2.3MW turbines) to track the species' reproductive success and nest locations, eagle night roosts, and flight activity, including use of the Merlin avian radar. The monitoring data fed into the design and impact assessment for the repowering project.

A vulnerability map for the white-tailed eagle was produced using monitoring data to identify in which areas the white-tailed eagle was the most and the least vulnerable. Collision risk modelling found that of the two repowering designs proposed, the 30 5MW turbine scenario (see Figure 5-6) is likely to have 32% of the collision risk compared to the existing operational wind farm. The 50 3MW turbine scenario is expected to have a collision risk that is approximately 71% of the existing operational wind farm.

The difference in collision risk between the two repowering scenarios and between the repowering scenarios and the existing wind farm was attributed to the reduction of the number of turbines and to better siting of individual turbines.

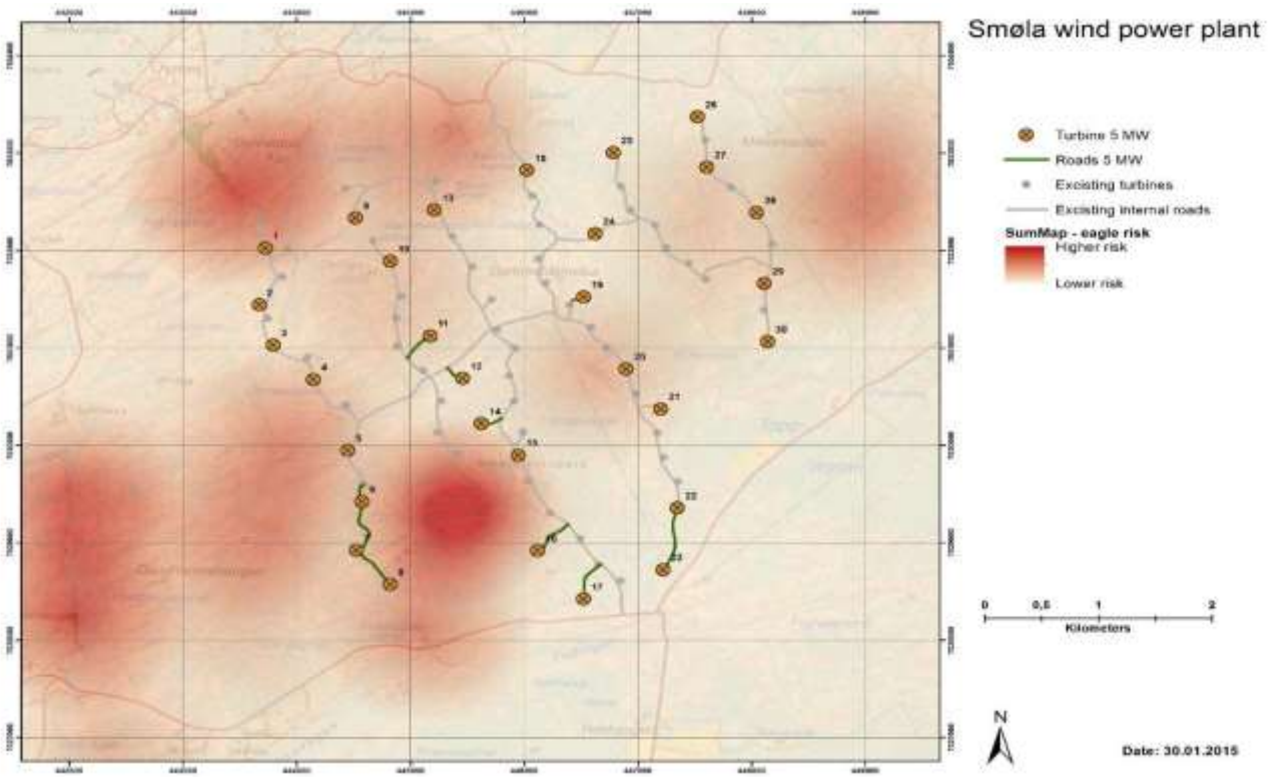

Figure 5-6: White-tailed eagle relative sensitivity map at the Smøla wind-power plant (5MW layout) collating the following data sources: nest site, chick production, flight activity and collision risk. The intensity of red shading indicates the degree of sensitivity, with dark red indicating high sensitivity.

Even though the data underpinning the assessments in the reports are very solid, there is still a degree of uncertainty, and therefore the authors acknowledged that is not possible to predict the exact effects of a repowered wind-power plant. Therefore, they recommend using an adaptive management plan (see also Chapter 7). Adaptive management includes creating the ability to adapt to the spatio-temporal conflict level in the repowered wind-power plant, i.e. where, when and to what extent conflicts may arise between birds and turbines in the new plant. This allows developers to implement mitigation measures at risky turbine locations and/or at specific times of the year (e.g. contrast painting rotor blades, making operational adjustments and using video-based warning systems).

Source: Dahl, E.L., *et al.* (2015)

Case study 5-15: Reducing the collision risk of species of tern by repowering the Zeebrugge Wind farm, Belgium

A linear wind farm dating from 1986, consisting of 24 turbines (10/12/2 wind turbines of resp. 200/400/600 kW with axle heights of resp. 23/34/55 metres and rotor diameters of resp. 22.5/34/48 metres) in the harbour of Zeebrugge, caused serious collision risks for a nearby breeding colony of Common Tern (*Sterna hirundo*), Sandwich Tern (*Sterna sanvicensis*) and Little Tern (*Sterna albifrons*) in a Natura 2000 site (Everaert & Stienen 2007, Everaert 2008).

Monitoring the results of the old wind park showed that the terns made food flights of between 0 and 50 metres, with most flights being between 0 and 15 metres. The monitoring involved making a thorough analysis of the flight height distribution.

The assessment carried out in designing the repowering of the wind farm concluded that no significant effect of the new wind park was to be expected, assuming the future flight height distribution pattern of the food flights would stay the same. By increasing the height of the wind turbines and limiting the number of wind turbines in the design of the new wind park, bird collision risk would be reduced.

The repowering of this wind farm in the harbour of Zeebrugge resulted in fewer but larger turbines. In 2009, 10 new wind turbines (850 kW) were installed with more spaces between them. The new turbines have an axle height of 65 metres and a rotor diameter of 52 metres. The bottom height of the wind turbine blades increased from 11-20.5 metres in the old wind park to 39 metres in the repowered wind park. So far, monitoring has shown that this has reduced the collision effect compared to the original situation before the wind farm was repowered.

Source:
Everaert J., (2007). Adviesnota INBO.A.2007.164. Instituut voor Natuur- en Bosonderzoek.
Everaert J., (2007). Adviesnota INBO.A.2007.84. Instituut voor Natuur- en Bosonderzoek.
Everaert J. & Stienen E. (2007).
Everaert J. (2008).

6. OFFSHORE: POTENTIAL EFFECTS

6.1 Introduction

This chapter reviews the main types of impacts that offshore wind energy developments could have on habitats and species protected under the Habitats and Birds Directives. The scope of the two Directives is clarified in Chapter 2.2.1, while the concept of assessing significance is explained in Chapter 3.1.

The purpose of this chapter is to provide developers, NGOs, consultants and competent national authorities with an overview of the potential impacts on different groups of EU-protected habitats and species. These potential impacts should be considered when developing or reviewing an offshore wind energy plan or project. However, as the identification of likely significant effects is always case specific, the real impact of a wind energy development on protected species and habitats will be highly variable.

Effects from offshore wind energy developments may arise in one or more of the five main phases of wind energy development:

- pre-construction (e.g. meteorological investigations, exploratory studies into sediment stability, and seabed preparation);
- construction (e.g. transport of material by vessels and construction of monopile[110] foundations; turbines; grid connection cables; fixed/floating turbines; etc.);
- operation (including maintenance);
- 'repowering' (changing the number, type and/or configuration of turbines in an existing wind farm);
- decommissioning (removing the wind farm or individual turbines).

When assessing the significance of effects, it is important to bear in mind that they may arise from the entire project footprint (including any associated infrastructure, such as grid cables), and may even arise from the onshore aspects of offshore projects (e.g. arrangements for landfall and onshore transmission).

The effects on habitats and species may be temporary or permanent. They may result from activities within or outside the boundaries of a Natura 2000 site. For mobile species, the impacts may potentially affect individuals well away from the associated Natura 2000 sites, such as marine mammals or seabirds foraging at large distances from the breeding colony. Significant effects may arise from the plan or project alone, and may occur at different times during the project's lifecycle. Plans and projects acting in combination may produce cumulative effects. These effects will be of growing importance, as offshore wind energy is projected to grow to meet renewable energy targets.

In the next subchapters, the main types of impacts are described for the major 'receptor' groups[111]. An overview is given in Table 6-1. In some instances, an impact may be positive, e.g. the creation of a new habitat or reef effects (see Box 6-1).

Box 6-1: The reef effect of offshore wind-farm foundations

The reef effect is one of the possible effects of offshore wind-farm foundations on marine biodiversity. It is particularly significant in marine areas without rocky soils such as large parts of the North Sea. Underwater constructions may function as artificial reefs, and the foundations may be colonised by a range of organisms. Although there is evidence that wind-farm structures are associated with greater diversity of benthic organisms (Lindeboom *et al.,* 2011) and increased densities of commercially significant fish (Reubens *et al.,* 2013), this may also alter the characteristics of local species composition and biological structure (Petersen & Malm, 2006). This potentially positive effect for marine biodiversity

[110] There are different types of wind turbine foundations. Most frequently, monopiles are used; these are quite simple structures, made up of a thick steel cylinder that is anchored directly to the sea bed. Other foundation types are a.o. jacket pin piles – foundations with a lattice framework that feature three or four sea bed anchoring points – or gravity foundations.
[111] Key receptor groups such as seabirds, marine mammals and marine habitats which potentially experience an impact of the offshore wind energy developments

should be taken into account when considering options for decommissioning. Fowler *et al.* (2018) highlight the potential negative effects, including to groups such as marine mammals, of full removal of structures from the marine environment (as currently required in line with OSPAR Decision 98/3; Jørgensen, 2012). Partial removal of these structures can have the potential advantage of providing a continued reef habitat. However, the potential biological communities that could be established on the wind-farm structures should be carefully assessed in relation to the conservation objectives of the site, including their effects on protected species and habitats, not least through the potential introduction of invasive alien species that could be established on newly built structures.

Table 6-1 Overview of potential types of impacts on major offshore receptor groups

Receptor	Potential impacts of offshore wind energy developments
Habitats	Marine habitat loss Marine habitat disturbance and degradation Smothering from suspended sediments falling out of suspension Creation of new marine habitats Changes to physical processes from the presence of new structures Contaminant release or mobilisation of historic contaminants
Fish	Electromagnetic fields Underwater noise disturbance Reef effects
Birds	Habitat loss and degradation Disturbance and displacement Collision Barrier effect Indirect effects Attraction (e.g. roosting opportunities)
Marine mammals	Habitat loss and degradation Noise disturbance and displacement (pile-driving noise and noise from shipping/helicopters) Acoustic impairment (injuries from underwater noise) Communication masking Collision with vessels Barrier effect Reduction of fishing pressure (no fishing zones) Water quality changes (contaminants + marine waste) Electromagnetic field effects on navigation Indirect effects Reef effect
Bats	Disturbance and displacement Collision Barrier effect Barotrauma Loss/ shifting of flight corridors and roost sites Indirect effects
Other species	Noise disturbance and displacement Electromagnetic fields Heat effects Creation of new habitats Water quality changes (contaminants + marine waste) Indirect effects

Compared to onshore wind energy, there are clearly differences in the nature of some activities associated with offshore wind energy development. These differences include the use of vessels to access sites and certain impact mechanisms which are unique to the aquatic environment such as underwater noise. However, the principles underpinning the mitigation measures for onshore wind also apply to offshore wind. These principles are outlined in the bullet points below.

- The ‘mitigation hierarchy’ applies, which means that measures to avoid negative effects in the first place must be considered and implemented before measures to reduce negative effects. It is also good practice to apply these measures at the source before considering measures for the receptor.

- The best way to minimise negative effects on EU-protected habitats and species is to locate projects away from vulnerable habitats and species (a practice known as 'macro-siting'). This can best be achieved through strategic planning at administrative, regional, national or even international level, in particular through the maritime spatial plans drawn up under the Maritime Spatial Planning Directive[112].
- Transboundary effects are very relevant in offshore wind energy, not only due to cumulative effects (e.g. on bird migration) but also because many wind farms are located close to the borders of the European Economic Zones (EEZ) of other Member States (or even cross-border projects in the future). According to the ESPOO Convention and the Protocol on Strategic Environmental Assessment (SEA Protocol, Kyiv (Jendroska *et al*., 2003[113])), the parties of the Convention are obliged to inform each other of transboundary effects and to take transboundary effects into account in their planning. Cooperation between the Member States and with countries outside the EU is also required when developing maritime spatial plans.
- Monitoring is not in itself a mitigation measure, but it is necessary to validate whether measures to avoid or reduce significant effects are effective.
- Mitigation measures must not be confused with compensatory measures, which are intended to compensate for damage that may be caused by a plan or project. Compensatory measures can only be considered in relation to the criteria set out in Article 6(4) of the Habitats Directive.

6.2 Habitats

6.2.1 Introduction

Ten habitat types (or habitat-type complexes) listed in Annex I of the Habitats Directive are treated as marine habitats for reporting purposes, and two of these are considered as priority habitat types (marked with *):

- sandbanks which are slightly covered by sea water all the time [1110]
- Posidonia beds (*Posidonion oceanicae*) * [1120]
- estuaries [1130]
- mudflats and sandflats uncovered at low tide [1140]
- coastal lagoons* [1150]
- large shallow inlets and bays [1160]
- reefs [1170]
- submarine structures made by leaking gas [1180]
- Boreal Baltic narrow inlets [1650]
- submerged or partly submerged caves [8330].

The above habitat types include coastal habitats, habitats of shallow seas, and habitats of deeper offshore waters (European Commission, 2013). Because offshore wind energy developments require access to the land ('landfall') onshore habitats also need to be considered when assessing offshore projects (see Chapter 5.2). Baseline data to support an appropriate assessment should be collected using the best available methods. Examples of baseline-survey methods are summarised in Box 6-2.

Box 6-2 Baseline survey for benthic habitats

Surveys are likely to be required to delineate Annex I habitat areas within the footprint of wind energy developments and within a delineated buffer zone. Detailed guidance on survey methods are sometimes available at national level[114]. Surveys for Annex I habitats could be part of a wider characterisation survey for the purposes of an environmental impact

[112] Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning; OJ L 257, 28.8.2014, pp. 135–145.
[113] Jendroska, Jerzy & Stec, Stephen. (2003). The Kyiv Protocol on strategic environmental assessment. 33. 105-110.
[114] See for example: 'Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK 4)': https://www.bsh.de/DE/PUBLIKATIONEN/_Anlagen/Downloads/Offshore/Standards/Standard-Investigation-impacts-offshore-wind-turbines-marine-environment_en.pdf?__blob=publicationFile&v=6 and 'Marine Monitoring Handbook': http://jncc.defra.gov.uk/page-2430#download.

assessment (EIA). Information sources such as EMODnet[115] may provide useful information on existing data on broader-scale mapping of seabed habitats.

If there is no recent (less than 1-2 years old) high-resolution mapping of a habitat's features, it is usually necessary to undertake detailed site-specific surveys before developing the project.

Habitat-classification schemes are a valuable tool in baseline surveys of subtidal and intertidal habitats. The Europe-wide EUNIS system[116] provides a list of 'biotopes', which are defined based on characterising species and associated physical characteristics, such as: (i) the substrata it occurs on; (ii) the depths at which it can be found; and (iii) the type of wave and tidal energy conditions with which it is associated. Useful guidance on assigning biotopes is provided in Parry (2015[117]).

Survey techniques are outlined in the bullet points below.

- Intertidal habitats
  - Transect, point or walkover surveys on foot or with vehicle support such as hovercraft.
  - Satellite remote sensing, airborne multispectral remote sensing, aerial photo-interpretation.

- Subtidal habitats
  - Observation by drop-down video, towed video or remotely operated vehicle. Direct observation by a diver may also be possible. Visibility conditions are an important consideration, although camera systems with freshwater housing may allow images to be obtained in turbid conditions.
  - Sampling using grab, core, dredge and/or trawl methods. Destructive techniques, especially trawls, need to be planned carefully in potentially sensitive areas.
  - Survey design can be optimized by using acoustic ground-discrimination systems such as side-scan sonar and multi-beam echo-sounders. These systems should be deployed before carrying out direct observations and using sampling techniques.

6.2.2 Types of impacts

6.2.2.1 What are the main types of impacts?

The main types of impacts of offshore wind-farm development on marine habitats are summarised in Table 6-2. In most cases, the effects listed summarise a potentially complex range of impacts. For example, habitat damage and disturbance may occur from any activity interacting with the seabed. This could include: (i) survey equipment such as grabs and cores; (ii) wash from propellers; or (iii) seabed preparation before installation of foundations and cables. These impacts can lead to effects that potentially act over a wide range of spatial scales and that can occur at any time during and after the life of the project. However, the principal periods of concern are as indicated in the project phases listed in Table 6-2.

Table 6-2 Types of impacts on habitats during the project's life cycle for offshore wind-energy developments

Main types of impacts	Project phase				
	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss (loss of existing habitat and replacement with another habitat, e.g. adding concrete, steel or rock structures)		X		X	X

[115] https://www.emodnet-seabedhabitats.eu
[116] https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification
[117] http://jncc.defra.gov.uk/pdf/Report_546_web.pdf

Habitat disturbance and degradation (including: (i) penetration, abrasion and compression of sediments; and (ii) construction of cables)	X	X	X	X	X
Smothering from suspended sediments falling out of suspension		X		X	X
Creation of new marine habitat		X			
Changes to physical processes from the presence of new structures		X	X		X
Contaminant release or mobilisation of historic contaminants		X	X	X	X
Indirect effects	X	X	X	X	X

Annex I habitats that are potentially vulnerable to effects from offshore wind energy development include ‘sandbanks which are slightly covered by sea water all the time’ [1110], ‘reefs’ [1170], and Posidonia beds [1120]. Posidonia beds are at risk from direct physical destruction and sedimentation changes in hydrographic regimes (see Bray *et al.*, 2016). Depending upon the location of the wind farm and related electricity export infrastructure, other habitats or habitat complexes could also be affected. These habitats and habitat complexes include ‘estuaries’ [1130], ‘mudflats and sandflats not covered by seawater at low tide’ (1140), and ‘large shallow inlets and bays’ [1160]. Some marine habitats, notably ‘submerged or partly submerged caves’ [8330] are unlikely to be affected by offshore wind energy developments.

Plans and projects need to consider which habitats may be affected by proposed activities in light of the types of impacts summarised in Table 6-2 above. Although works such as geophysical and geotechnical surveys are unlikely to give rise to significant effects on habitats, the potential for geotechnical cores or other activities to result in direct habitat loss/disturbance to protected habitats should be considered. Repowering activities also require consideration since these may involve activities with effects similar to other phases. Potentially, repowering activities may even extend the duration of existing effects beyond the period originally assessed.

Intertidal and subtidal habitats can be affected by wind energy developments through: (i) habitat loss under the footprint of turbines and associated infrastructure; (ii) disturbance as a result of sediment dispersion/sedimentation arising from different activities, which can lead to smothering of the seabed, altering the physical structure of habitats or causing remobilisation of pollutants; and (iii) temporary disturbance from the interaction of operations with the seabed, including use of ‘spud-legs’ from jackup rigs[118], vessel anchors etc. Long-term effects on habitats include the introduction of new artificial substrates that can attract benthic and other organisms (Wilhelmsson, 2010; Hiscock *et al.*, 2002). Finally, Annex I habitats can be affected by the exclusion of other activities that were previously present, such as fisheries. Benthic habitats which have been seriously degraded due to bottom-trawling activities could then recover.

Most offshore wind farms, and their associated cabling, are currently located in areas of relatively soft sediment (e.g. sandy seabeds with varying proportions of finer sediment and coarser gravels, cobbles etc.). Sandbanks [1110] and reefs [1170] have therefore been the focus of most of the appropriate assessments since they are vulnerable to habitat loss. The principal concern has been direct loss of these habitats under the footprint of wind-turbine foundations and associated infrastructure.

The introduction of hard surfaces in an area dominated by sandy sediments has often resulted in a significant change in the benthic communities (Meissner & Sordyl, 2006). Although this change may be viewed positively, the marked change in conditions might result in significant effects if the existing habitats are protected in a Natura 2000 site. Technical structures or other man-made hard substrates result in: (i) permanent changes in sediment structure; (ii) the sealing of marine sediment; and (iii) the resulting loss of soft-bottom habitats.

[118] Type of mobile platform that is anchored in the seabed by use of barge pin-anchor systems called spud-legs.

Therefore, man-made placement of hard substrates is not necessarily an ecological improvement of marine habitats. The condition and conservation objectives of Natura 2000 sites should be considered in assessments, and cautiousness is required where there is limited information about true historic baseline conditions.

Another aspect that needs to be emphasised is the difference between fixed and floating wind-turbine technologies, including the nature of the seabed in which either of these technologies will be located. Some types of fixed wind foundations such as suction buckets require no pile driving or drilling. This means that the likelihood of significant effects is low compared to monopoles or other piled foundation types. Floating wind-turbine energy has a much lower footprint in terms of habitat destruction.

6.2.2.2 How is significance assessed?

Significance has largely been determined by quantification of the area of habitat that is likely to be lost, degraded or disturbed compared with the total habitat area. This requires a good understanding of the distribution, structure and functions of habitats.

The significance of the effects can be influenced by several factors: biology, environment, plan design, and project design. Box 6-3 presents the main factors taken into account when assessing significance.

Box 6-3 Factors determining the assessment of significance

Biological (Tillin *et al.*, 2010):

- resistance (whether a receptor can absorb disturbance or stress without changing character);
- resilience (recovery potential);
- sensitivity (the likelihood of change when a pressure is applied to a feature (receptor), which is a function of resistance and resilience).

Environmental

- Soil or sediment type and morphology
- Water quality and quantity
- Existing activities such as nature conservation activities that may be disturbed, leading to a change in environmental conditions

Plan design or project design:

- number of wind turbines;
- foundation design, in particular the footprint area;
- any scour protection and installation methods, especially if the enabling works include habitat clearance over a wider area (e.g. sand-wave levelling);
- number, length and burial method(s) of cables (and use of protective armouring on cables);
- other associated activities (e.g. requirement to anchor vessels or deploy jack-up legs, disposal areas for drill arisings or dredge arisings etc.);
- duration of the construction activities and their spatial scale;
- decommissioning plans – whether infrastructure (including foundation bases and protective armour) will be left or removed.

The Marine Evidence-based Sensitivity Assessment (MarESA (Tyler-Walters *et al.*, 2017)) is an evidence-based, expert-judgement approach for informing the assessment of significance. Table 6-3 provides a summary of the MarESA approach for biotopes that may occur within – or that are typical of – Annex I habitat types. The summary focuses more specifically on abrasion. The effects of physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats are relevant to epiflora and epifauna living on the surface of the substratum. Abrasion could be caused by sediment sampling, vessel anchoring, or compression of sediments by jack-up barge legs. Benchmarks (quantitative or qualitative) are an important part of the MarESA assessment process. They describe the pressure in terms of the magnitude, extent, duration and frequency of the effect.

Table 6-3 Marine habitat sensitivity, resistance and resilience in relation to abrasion

Habitat type (example of a biotope)	Resistance	Resilience	Sensitivity

Sandbanks which are slightly covered by sea water all the time [1110] (sublittoral sand in variable salinity)	Low	High	Low/medium[119]
Posidonia beds (*Posidonion oceanicae*) [1120]	Medium	Low	Medium
Estuaries [1130] (*Hediste diversicolor*, *Limecola balthica* and *Scrobicularia plana* in littoral, sandy mud shores)	Medium	High	Low
Mudflats and sandflats uncovered at low tide [1140] (*Zostera sp*. beds on lower shore or infralittoral clean or muddy sand)	Low	Medium	Medium
Coastal lagoons* [1150] (Sublittoral mud in low or reduced salinity (lagoons))	Medium	High	Low
Large shallow inlets and bays [1160] (*Arenicola marina* in infralittoral mud)	High	High	Not sensitive
Reefs - biogenic or geogenic [1170] (*Sabellaria spinulosa* on stable circalittoral mixed sediment)	None	Low/Medium	Medium/High

*priority habitat

Where there is uncertainty (about either the potential effects or the design parameters of wind farms) worst-case assumptions should be made. For example, the use of subsea cable protection (e.g. rock armour) can substantially increase the footprint of habitat loss associated with cable installation. However, the amount of rock protection required cannot be estimated until the success of cable burial is known. Such estimates need to be as accurate as possible and informed by appropriate information, such as a geotechnical survey of ground conditions.

Uncertainties and challenges encountered in the assessment of likely significant effects on offshore habitats (and which may require the collection of additional baseline data or the application of the precautionary principle) are summarised in Box 6-4.

Box 6-4 Key challenges in assessing the likely significant effects for offshore habitats

All effects

- Data availability, notably in relation to broad-scale habitat distribution to inform: (i) plan-level assessments; or (ii) detailed, project-specific surveys and assessments.
- Lack of certainty about project-design parameters, notably the amount of material required for cable protection and its location. There is sometimes also uncertainty about the effectiveness of cable protection and burial approaches, e.g. in areas of dynamic seabed where sand-wave clearance may be required before burial. If remedial works are required, this may result in renewed risk to Annex I habitats through increases to key parameters in the design envelope.
- In some cases, there is incomplete information on the extent of existing infrastructure affecting Annex I habitats. For example, if the seabed area covered by rock protection within a Natura 2000 site is not known it is difficult to make an informed cumulative assessment.
- Spatial and temporal variability of habitats. The marine environment is dynamic. For example, certain habitats such as sandbanks [1110] may be mobile, and biological communities (e.g. biogenic reefs [part of 1170]) are inherently variable within and between seasons.
- Understanding the sensitivity of habitats and associated species to wind energy development activities, in particular their resistance (tolerance) and resilience (ability to recover). There has been relatively little work to improve the evidence base from reviews of post-development monitoring.

6.2.3 Mitigation measures

The appropriate siting of offshore wind energy developments is the most effective way for avoiding potential conflicts with Natura 2000 sites and EU protected species and habitats.

Other mitigation measures to minimise the effects on marine habitats include selecting the least disturbing methods for activities such as cable installation and seabed preparation. For example, releasing the dredged

[119] https://www.marlin.ac.uk/habitats/annex1
https://inpn.mnhn.fr/programme/sensibilite-ecologique?lg=en

material close to the seabed via a fall pipe allows for more accurate placement of material within a disposal zone and may result in lower levels of suspended solids than releasing the material close to the surface. The selection of sediment-disposal areas can also: (i) take into account the proximity of sensitive areas of seabed habitat; and (ii) ensure that material is returned to contribute to sediment-transport pathways at an appropriate spatial scale for features such as sandbanks.

Good practice in preventing water pollution and controlling invasive non-native species is widely available in Member States and internationally (e.g. the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)). It is therefore not considered further.

Case study 6-1 describes the measures taken for the restoration of a degraded habitat during the construction of an offshore wind farm in Denmark. Although this wind farm is not located in a Natura 2000 site, this approach could be relevant for Natura 2000 sites that protect Annex I reef habitats.

Case study 6-1 Restoration of degraded habitat for the construction of the Anholt offshore wind farm in Denmark

To construct the Anholt offshore wind farm in Denmark, around 5,000 large stones of up to 30 tonnes had to be moved. Due to their extensive removal for use in harbour piers, coastal-protection facilities and other man-made facilities, rocky reefs have become a rare natural element in Denmark. With the agreement of the Danish Nature Agency, the developer of the Anholt offshore wind farm, DONG Energy (now Ørsted), did not simply rearrange the boulders on the reef where the wind farm was to be located. Instead, DONG used the stones to create approximately 28 artificial reefs with caverns of various sizes within the wind farm. This led to an increase in biodiversity. In this way, the wind farm has helped create optimum breeding and living conditions for animals and plants, in particular those attached to hard substrates[120].

Such measures may be especially beneficial where natural reef-habitat features have been degraded. This has been the case in Denmark, where many areas with stone reefs, particularly in shallow waters (less than 10 m deep) and coastal areas, have been destroyed due to the removal of stones and boulders for use in the construction of piers, breakwaters, and other facilities (Dahl *et al*., 2015).

It is important to note that the Anholt wind farm was not in a Natura 2000 site, and no Annex I reef habitats were affected by it. However, this approach highlights a potential pathway to restore Annex I reef habitats and contribute to achieving their favourable conservation status as required by the Habitats Directive.

6.3 Fish

6.3.1 Types of impacts

Most fish species listed in Annex II of the Habitats Directive are fully freshwater. There are a few migratory species such as shad (*Alosa spp*.) and lamprey, which spend part of their life cycle in the sea and part of their life cycle in fresh water. The Atlantic salmon (*Salmo salar*) is only listed when present in freshwater. Only a few fish species that spend part of their life cycles in the sea are listed in Annex IV, notably the Adriatic and European sturgeon (*Acipenser naccarii* and *A. sturio* respectively). Anadromous (fish that move between the sea and rivers) populations of *Coregonus oxyryhnchus* in certain sectors of the North Sea are listed in Annexes II and IV, but this species may be extinct in the marine environment (Freyhof & Kottelat, 2008).

Since Natura 2000 sites designated for Annex II fish species tend to be located inland or in estuaries, it is unlikely that they overlap with offshore wind farms. The principal impacts considered for these Annex II fish species are those where effects are propagated over distance, for example disturbance from underwater noise and changes in water quality (for example due to suspended sediment). Electromagnetic fields (EMF) from 'export' cabling (export cabling is cabling used to send electricity from a wind farm to the shore) is also a potential type of impact, and is further discussed in the guidance document *Energy transmission infrastructure and EU nature legislation* (European Commission, 2018a). The ability of sturgeon to detect EMF has been noted, although the likelihood and significance of any effects are not well understood (Boehlert & Gill, 2010). Migratory salmonids may also be able to detect EMF, and the possibility of this affecting the migration of young fish or returning adults should be considered (Gill *et al*., 2005). However, there is considerable uncertainty

[120] http://www.mega-project.eu/assets/exp/resources/Anholt_case_template_(2).pdf

about whether magnetic fields or induced electrical fields have adverse effects and whether these effects might be ecologically significant.

Underwater noise may need to be considered if an offshore wind energy development is sufficiently close to a designated site in coastal or estuarine waters. This is because there may be effects from the loudest activities involved in the construction of the wind farm (e.g. foundation piling and/or detonation of unexploded ordnance (UXO)). Popper *et al*. (2014) propose ranking species according to their sensitivity to underwater noise, based on the presence or absence of a swim bladder. Fish with swim bladders, including Atlantic salmon and the shad species, are understood to be sensitive to sound pressure. In the case of shad, the swim bladder is close to the ear and their sensitivity to noise is relatively greater. Fish without a swim bladder, such as lamprey, are sensitive only to particle motion and not to sound pressure.

According to Popper *et al*. (2014) the most sensitive species, such as shad, could be subject to disturbance effects from noise for 'thousands of metres' (i.e. kilometres), as opposed to hundreds of metres for species such as salmon, and tens of metres for species such as lamprey. It must be emphasised that these estimates are tentative. Moreover, there is some evidence that herring, a fully marine species in the same family as shad, may be able to perceive piling noise, and be disturbed by noise at distances of up to 80 km from the noise source (Thomsen *et al*., 2006). But generally, disturbance effects are expected to occur over much smaller distances of up to some low tens of kilometres. For example, Boyle and New (2018) suggested a range of up to 15.4 km within which fish could be disturbed by the sound of piling. These ranges suggest that careful consideration of noise effects is warranted where foundation piling, or other loud activities such as UXO detonation, occur within tens of kilometres from a Natura 2000 site designated for shad.

Marine mammals and fish-eating seabirds, protected under the Birds and the Habitats Directives, rely on healthy fish populations. Assessments of offshore wind energy developments therefore need to consider the potential effects on a wider set of species than those listed in the Annexes of the Habitats Directive.

6.3.2 Possible mitigation measures

There is limited experience of measures taken specifically to avoid or reduce effects on Annex II fish species. Seasonal restrictions on pile driving have been considered in a few cases to avoid potential effects on salmonids during their migration. This measure has been taken as a precaution given the uncertainty about the likely range of any disturbance effect. There are more examples of seasonal restrictions on piling to protect fish species which are not listed in Annex II during their breeding season. These restrictions have mainly targeted commercially significant species, such as herring, which are also of trophic importance for other EU-protected species, e.g. as prey for marine mammals.

Mitigation measures to reduce underwater-noise levels for marine mammals are also expected to be effective for fish.

Concerns about EMF effects are generally addressed by burying cables at depths of 1 metre or more. Most EMF reduction is achieved by burial, or by covering the cable with protective material such as rock armour, since the strongest fields are present on the cable surface. Although burial reduces the EMF magnitude in the seawater above the cable, the resultant magnetic or induced electrical fields may still be detectable by some species even with deeper burial (Gill *et al*., 2009).

6.4 Birds

6.4.1 Introduction

The interaction between birds and offshore wind energy developments has been studied extensively within and beyond the EU. As a result, there are many national guidance documents on birds and wind energy developments that detail the appropriate methods for collecting baseline data. A comprehensive list of national guidance documents is given in Appendix E.

Baseline data to support an assessment of significance of the effects should be collected using the best available scientific methods (for example Camphuysen *et al*., 2004; Maclean *et al*., 2009; Thaxter and Burton, 2009). A comprehensive review of survey methods was published by Smallwood (2017). Example baseline surveys are summarised in Box 6-5. Given the wide-ranging nature of birds, strategic surveys at regional, national or even international scales are especially important to provide baseline information on population levels and support a biologically meaningful assessment of plans and projects. These types of surveys are especially important when considering cumulative effects. However, this does not reduce the need for carefully targeted surveys at a local (wind-farm) level to inform project-level assessments.

Box 6-5 Example of baseline surveys for offshore birds

- Seabird colony counts: conducted in the absence of existing monitoring data on the Natura 2000 site in question.
- Where existing seabird colony-count data are not available, or where they are not reliable for the purposes of an impact assessment, seabird colony counts should be undertaken to establish a relevant baseline. Where possible, counts should follow the methodology used for the national census scheme to allow for comparability. Counts should be undertaken by ornithologists with relevant, seabird colony-count experience, especially when counts are conducted from boats. Depending on the size of the colony and the number of personnel available, counts may take several days to complete. Counts should be conducted at the time of day (e.g. 07.00-17.00h) and the time of year (e.g. May-June) that most accurately captures the presence and abundance of all species within the seabird assemblage. Species-specific surveys may be required for nocturnal species that nest underground or in between rocks. For a review of methodologies, see Bibby *et al*., 2000.
- Land-based vantage-point surveys if turbines are very close to shore.
- Boat-based (can be used if transit to the site is not too long) or digital aerial transect surveys (digital or video) — to determine species abundance, distribution at sea, and species flight-height distributions. There can be issues with all of these methods in understanding flight heights, attraction behaviour (conducted with a boat-based assessment), species identification etc.
- Bird tagging to understand foraging behaviour during breeding and to understand bird movements in the non-breeding season.
- Radar: use of radar systems to estimate bird flux, bird densities, flight direction, and flight height, particularly where migratory birds are likely to be present in large numbers. Radar should be used in conjunction with visual observation to identify species. Although radar can be used to automatically record such data over very large areas, these data are only valuable for the assessment of species-specific effects when calibrated through direct visual observation. For this reason, radar is not widely used in impact assessments for offshore wind energy developments. Nevertheless, radar may be useful in some circumstances where data cannot be obtained through direct visual observation or through GPS tracking.

6.4.2 Types of impacts

6.4.2.1 What are the main types of impacts?

The types of impacts on birds from offshore wind energy developments are largely similar to those identified for onshore wind energy developments, although cumulative effects might be more significant for offshore. These types of impacts have been extensively reviewed (e.g. Perrow, 2019) and are summarised in Box 6-6. The relationship between the types of impacts and the project's lifecycle is highlighted in Table 6-4. Each type of impact has the potential to influence individual survival and reproductive success. This can result in changes in the demographic parameters of a population, the outcome of which may be a measurable change in population size.

Box 6-6 Types of impacts on birds

- Collision: the fatal interaction between birds in flight and wind-turbine structures.
- Disturbance and displacement: avoidance behaviour by birds can effectively result in habitat loss. However, there are few studies that assess whether this may also result in population impacts (Searle *et al*., 2014; Warwick-Evans *et al*., 2017; Garthe *et al*., 2015).
- Barrier effects: the wind farm functioning as an impenetrable area to flying birds, resulting in additional flight distances and increased energy expenditure.
- Habitat loss and degradation: the removal or fragmentation of supporting habitat that birds would otherwise use.
- Indirect effects: changes of prey abundance and availability may be direct or mediated via changes in habitats. These changes may be positive (Lindeboom *et al*., 2011) or negative (Harwood *et al*., 2017) but there is limited evidence of their effect on the bird population.

Table 6-4 Types of impacts on birds during the project's lifecycle for offshore wind energy developments

Types of impacts	Project phase

	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss and degradation		X	X	X	X
Disturbance and displacement	X	X	X	X	X
Collision			X	X	
Barrier effect		X	X	X	
Indirect effects	X	X	X	X	X
Attraction (e.g. roosting opportunities)			X	X	

6.4.2.2 How is significance assessed?

The likely significant effects of wind energy developments on birds are typically assessed in a two-step process. The first step involves quantifying the magnitude of the effects in bird mortality. This is followed by the second step, which involves assessing the change in the population with reference to the conservation objectives of the site in question.

Several factors can influence the significance of effects: biology; environment; plan design; and project design. Box 6-7 summarises the factors typically taken into account in both the design of baseline-data collection methods and the assessment of significance.

Box 6-7 Factors determining the baseline-data collection methods and the assessment of significance in relation to offshore wind energy and birds

All effects

- Long-lived, slow-turnover (k-selected) species, such as seabirds, are more vulnerable than small, short-lived (r-selected) species such as passerines.
- Small and threatened populations (e.g. Annex I species) are more vulnerable to additional sources of mortality than large populations that are stable or growing.
- Cumulative effects.

Collision

- The seasonal variation in the number of bird movements.
- Avoidance behaviour, resulting in decreased collision risk.
- Attraction behaviour, resulting in increased collision risk.
- The diurnal variation in flight characteristics such as speed, height and direction.
- Flight speed.
- Flight height.
- Nocturnal flight activity (which may increase collision risk).
- Turbine placement and wind-farm configuration (i.e. in relation to flight paths).

Disturbance and displacement

- Local bird abundance (e.g. species groups such as divers (gaviiformes) and sea ducks (Garthe *et al*., 2015)).
- Seasonality – greater wind-farm avoidance has been observed during the non-breeding season in relation to onshore wind energy developments.

Barrier effects

- Seasonality – the increased cost of repeated diversions around a wind energy development made by breeding birds moving between their nests and foraging areas may be more substantial than the energetic costs associated with the barrier effect imposed on migrating birds diverting around a wind energy development. This very much depends on the location of the wind farm and the flight paths.

Habitat loss and degradation

- Flexibility of species in its habitat use, and the extent it can respond to changes in habitat conditions.

Indirect effects

- The sensitivity and vulnerability of habitats and prey species to wind energy development activities, combined with the effect on birds resulting from potential changes in habitat and the composition of prey species.

Sources:
Villegas-Patraca *et al*., 2012; Hötker, 2017; Peterson and Fox, 2007.

The approaches typically used to estimate bird mortality and determine significance are reviewed in Laranjeiro *et al*. (2018) and summarised in Table 5-9. More than two approaches may be combined to inform the assessment. For example, a collision-risk model may be used to estimate bird mortality, and this estimate may then be subjected to a population viability analysis to assess the potential population consequence of the additional mortality. In Scotland, population models (population viability analysis) using counterfactual metrics are often applied.

Monitoring is essential to ensure that the scientific basis underpinning the conclusions of an assessment remain valid in the long term. The need for general approaches to monitoring is discussed in Chapter 7. For birds, the focus of monitoring is typically on collision risk and understanding if the predictions of collision-risk models hold true in reality.

Box 6-8 summarises the uncertainties and challenges encountered in the assessment of significance of effects on birds. These uncertainties and challenges may require additional baseline-data collection or the application of the precautionary principle.

Box 6-8 Key challenges in assessing likely significant effects on birds

All effects

- The generic ranges between foraging areas and breeding sites are based on small samples[121].
- Lack of knowledge on the proportion of birds from breeding colonies in special protection areas (SPAs) present in the non-breeding season[122].
- Understanding cumulative effects of plans and projects, especially where these occur across multiple countries and involve migratory species.

Collision

- Generic flight-height distributions are based on small samples (see Case Study 6-2).
- Avoidance rates are based on small sample sizes.
- Flight speeds are based on small sample sizes.
- Limited empirical data on nocturnal flight activity.

Disturbance and displacement

- Limited species-specific empirical data on displacement rates and the spatial extent to which displacement effects occur at sea.
- Limited empirical data supporting index-based model predictions.

Barrier effects

- Limited empirical data because: (i) previous studies have applied inappropriate methodologies; (ii) previous studies have not differentiated barrier effects from displacement effects; and (iii) there are limitations in the radar techniques (e.g. in terms of species identification).

[121] See for example, 'Combining habitat modelling and hotspot analysis to reveal the location of high-density seabird areas across the UK' (https://www.rspb.org.uk/globalassets/downloads/documents/conservation-science/cleasby_owen_wilson_bolton_2018.pdf).
[122] See for example, 'Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales' (http://publications.naturalengland.org.uk/file/5734162034065408)

- Limited empirical data on breeding birds because previous studies have focused on migratory birds.
- The cumulative barrier effect to long-distance migrating birds of avoiding multiple arrays along the course of their migration route remains unstudied.

Habitat loss and degradation

- Limited empirical data supporting threat identification or index-based model predictions.
- Extent of functionally linked land or sea beyond the boundary of an SPA which is necessary to maintain or restore the favourable conservation status of a species.

Indirect effects

- Limited empirical data on the sensitivity and vulnerability of prey species and their importance to the survival and reproductive success of the bird species in question.

Case Study 6-2 Estimating the flight height of seabirds using LiDAR

Problem

Estimates of collision risk are calculated using collision-risk modelling; typically using the Band model (Band, 2012). A key input parameter in the Band model is the height at which birds fly. A range of methods exist for either measuring or estimating the flight heights of birds, but validation of these flight heights appears to be limited or lacking (Thaxter *et al*., 2016). This has resulted in considerable uncertainty over the estimation of collision rates, and this may result in the application of overly precautionary assessment methods.

Solution

Recent advances in light detection and ranging (LiDAR; light radar) and digital aerial imaging make it possible to collect more accurate estimates of the altitude of birds in flight.

Practical/technical considerations

To collect data on the flight height of seabirds, an aircraft equipped with an appropriate LiDAR scanner synchronised with a digital camera is required. As with traditional digital aerial and boat-based surveys, the key limiting factor in using LiDAR to estimate the flight height of birds at night is the need to confirm the presence of a bird and identify the species concerned from digital imagery.

Advantages

Unlike other approaches, LiDAR is capable of measuring seabird flight heights with a high degree of precision, typically within one metre (Cook *et al*., 2018). The uncertainty associated with measurements of seabird flight height from LiDAR is far lower than the uncertainty associated with measurements made using other technologies. Furthermore, flight heights are estimated relative to the sea surface, helping to overcome difficulties associated with negative flight heights that may be recorded when using digital aerial surveys, GPS tags, or laser rangefinders (Cook *et al*., 2018).

Disadvantages

Setting up an airborne LiDAR scanner synchronised with a digital camera is currently much more expensive than conventional digital aerial surveys.

A key limitation of LiDAR estimates of seabird flight height is that sea-swell may interfere with the detection of birds in flight, resulting in a high false-positive rate. Cook *et al*. (2018) used a lower threshold of 1-2 m above sea level. As a consequence, the flight-height distributions derived from this technique will be biased against birds flying below 1-2 m above sea level. Such an overestimate in the proportion of birds flying at higher altitudes is likely to lead to a precautionary assessment of collision risk, although it is considered unlikely that this assessment would be overly precautionary.

Source: Band, 2012; Cook, 2018; Thaxter, 2016.

6.4.3 Possible mitigation measures

6.4.3.1 Introduction

This chapter provides an overview of possible mitigation measures that have been proposed for – or applied to – offshore wind energy developments. The limitations of those measures should be taken into account, especially when wind turbines are installed in sites with many birds. There is also great uncertainty as to whether some of the measures listed will be effective. The appropriate siting of wind farms and their associated infrastructure (macro-siting) is the most obvious mitigation measure to avoid any negative impacts on birds and wildlife in general.

The following chapter therefore describes mitigation measures and their effectiveness in avoiding and reducing significant effects on birds once a wind energy development has been properly macro-sited.

6.4.3.2 Infrastructure design: Number of turbines and technical specifications (including lighting)

This measure, as described in Chapter 5.3.3.3 (onshore), also applies to offshore wind energy developments. Infrastructure design can help reduce collision risk, but may also influence displacement and barrier effects.

Using baseline field-survey data or operational monitoring data with predictive modelling (such as collision-risk models) makes it possible to explore the influence of turbine design and the number of turbines. This can help when formulating an optimal design of low ecological risk.

Modelling by Johnston *et al*. (2014) demonstrated statistically that raising hub height and using fewer, larger turbines are effective measures for reducing collision risk.

Burton *et al*. (2011) found that, although a range of technologies and techniques have been proposed to reduce bird collisions within different industrial sectors, few were found to have been tested extensively on either onshore or offshore wind farms. Of the measures they reviewed, those most likely to reduce collision risk for birds were identified, and these included the deployment of decoy towers[123]. However, the deployment of decoy towers was identified as only likely to have an effect in areas where there are large concentrations of auks and divers.

On the attraction of birds to lighting, the available evidence from the literature (Burton *et al*., 2011) suggests that the most effective mitigation measures include: (i) switching from steady, burning red lights (designed to warn aircraft and shipping) to lights which flash; or (ii) the use of blue/green steady warning lights. However, the possibility of applying these measures must be checked against national and regional regulations.

6.4.3.3 Scheduling: Avoiding, reducing or phasing activities during ecologically sensitive periods

Scheduling aims at avoiding or reducing the disturbance and displacement of birds during certain critical periods. Scheduling may be of most use during construction, repowering and decommissioning, rather than during operation. Scheduling means that activities are either suspended or reduced during ecologically sensitive periods. Another scheduling option is to phase the activities, so that they continue but only at less sensitive locations. This can be done by using: (i) existing ecological knowledge of the species likely to be present at the wind energy development; (ii) baseline field-survey data; or (iii) operational monitoring data.

In contrast to onshore wind farms, this measure is likely to be less applied for offshore wind farms. No examples are known of offshore wind farms where this measure was applied. For offshore wind, the ability to schedule to avoid effects is very limited, largely due to the scale of construction and the likely construction timetable. The increased capability of construction vessels also means that weather is largely the only constraint to construction offshore.

6.4.3.4 Curtailment: Timing of turbine operation

Just as for onshore wind energy, the use of curtailment can be effective in avoiding or reducing the risk of bird collision at offshore wind farms.

The temporary shutdown of turbines is one of the measures that can help reduce the risk of bird collision (Burton *et al*., 2011). The German Ministry of Environment recommends: (i) temporarily shutting down turbines during mass-migration events to reduce collision risk (especially in bad weather and visibility conditions) and

[123] Towers placed round the perimeter of a wind farm to deter birds from entering, as outlined by Larsen & Guillemette (2007).

(ii) rotating the rotor plane out of the direction of migration[124]. Implementation of these measures requires: (i) good prediction models for migration; and (ii) surveys of migration intensity in the immediate surroundings of wind farms.

However, there is a need to model the effects of different and realistic shutdown strategies on seabirds.

6.4.3.5 Acoustic and visual deterrents

The use of deterrents aims at reducing the risk of collision.

Deterrents typically involve the installation of devices that emit audible or visual stimuli constantly, intermittently or when triggered by a bird-detection system. Passive deterrents such as painting can also be applied to the turbine towers and blades.

The evidence for the effectiveness of such techniques remains limited, and it is likely that their effectiveness is highly site-specific and species-specific.

6.5 Marine mammals

6.5.1 Introduction

The information provided in this chapter is relevant to marine-mammal species listed under both Annex II and Annex IV of the Habitats Directive (see Table 6-5). Annex II species are those for which Natura 2000 sites have to be designated and are therefore the focus of this guidance document in relation to appropriate assessment. However, the information in this chapter is also relevant to assessments for Annex IV species requiring strict protection under the Habitats Directive. A list of national guidance documents relevant to marine mammals is given in Appendix E.

Table 6-5 Marine mammal (seal and cetacean) species included in Annex II and IV of the Habitats Directive. (Y = Yes; N = No)

Species	Common name	Annex II (Natura 2000)	Annex IV (strictly protected)
CETACEA			
Phocoena phocoena	Harbour porpoise	Y	Y
Tursiops truncatus	Bottlenose dolphin	Y	Y
Cetacea (all other species)	Whales, dolphins and porpoises	N	Y
PHOCIDAE			
Halichoerus grypus	Grey seal	Y	N
*Monachus monachus**	Mediterranean monk seal	Y	Y
Pusa hispida botnica	Baltic ringed seal	Y	N
*Pusa hispida saimensis**^	Saimaa ringed seal	Y	Y
Phoca vitulina	Harbour seal	Y	N

* priority species, for the conservation of which the EU has particular responsibility because of the proportion of their natural range which falls within the European territory of the Member States to which the Treaty establishing the European Economic Community applies.

[124] https://www.bfn.de/en/activities/marine-nature-conservation/pressures-on-the-marine-environment/offshore-wind-power/minimising-the-impacts-of-offshore-wind-farms.html

^ Saimaa ringed seals inhabit Lake Saimaa in Finland and are therefore not anticipated to be relevant to wind power projects unless these impinge on their habitat.

Given the wide-ranging nature of marine mammals, strategic surveys at regional, national or even international scales are important to: (i) provide information on baseline population levels; and (ii) support biologically meaningful assessment of plans and projects, especially on cumulative effects. Such surveys are likely to be coordinated at a national or regional level, but they may also need to be complemented by survey work at plan level or project level to provide higher-resolution local data.

An example of a relevant, large-scale (international), long-term, marine-mammal survey is the SCANS programme[125] (Small Cetaceans in European Atlantic waters and the North Sea). This programme is supported by the EU and the governments of Denmark, France, Germany, the Netherlands, Norway, Portugal, Spain, Sweden and the UK. The programme has used a combination of surface vessels and aircraft as survey platforms.

Baseline data to support an appropriate assessment should be collected using the best available methods. It is not possible to provide a simple template for baseline surveys or monitoring (whether this be project-level work or large-scale strategic work) because of the many parameters that must be taken into consideration. For example, it is not necessarily appropriate for marine-mammal surveys to be 'bolted onto' seabird surveys, whether these be aerial based or vessel based. Macleod *et al*. (2010) pointed out that current approaches generally appear to involve adding marine-mammal surveys to surveys that have been optimised for seabirds. They argue that this approach to the problem is incorrect if the variance around seabird surveys is lower than the variance around marine-mammal surveys, which is almost certainly the case. Basic guidance on survey methodologies is provided in Box 6-9.

Box 6-9 Information on marine mammal distribution and guidance on survey methodologies

Large-scale international-to-regional distribution surveys

- SCANS surveys were conducted in 1994 (SCANS I), 2005/07 (SCANS II) and 2016 (SCANS III)[126].
- Summary by OSPAR Commission[127].
- Scottish East Coast Marine Mammal Acoustic Study (ECOMMAS)[128].
- The Baltic Marine Environment Protection Commission (HELCOM, also known as the Helsinki Commission) Baltic Sea marine-mammal monitoring[129].
- SAMBAH[130] – Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise: the LIFE-funded SAMBAH was completed in 2016 and was an international project involving all EU countries around the Baltic Sea.
- ACCOBAMS, in particular the large-scale survey of summer 2018[131].

Survey/monitoring methods

- Useful information on the advantages and disadvantages of alternative survey methodologies is provided by Macleod *et al*. (2010)[132].
- Limited guidance has been found on appropriate survey and monitoring methods for marine mammals in relation to offshore wind energy developments. National-level monitoring programmes (and monitoring at higher levels) provide relevant information to many industrial sectors and species-conservation programmes. These monitoring programmes are coordinated and often undertaken by multiple agencies after detailed planning. Project-level surveys and monitoring for marine mammals could employ visual-survey and/or acoustic detection techniques that are vessel based or aerial based. These need to be appropriate to the species and environment in question[133].

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[125] https://synergy.st-andrews.ac.uk/scans3/
[126] https://synergy.st-andrews.ac.uk/scans3/
[127] https://oap-cloudfront.ospar.org/media/filer_public/2f/1e/2f1eeeaf-9e63-4ca2-b7a5-8d6e76a682e5/cetacean_abundance_other.pdf
[128] http://marine.gov.scot/information/east-coast-marine-mammal-acoustic-study-ecommas
[129] http://www.helcom.fi/action-areas/monitoring-and-assessment/monitoring-manual/mammals
[130] www.sambah.org
[131] http://www.accobams.org/main-activites/accobams-survey-initiative-2/asi-preliminary-results/
[132] https://tethys.pnnl.gov/sites/default/files/publications/SMRU_2010_Monitoring.pdf
[133] See for example: 'Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK 43)': https://www.bsh.de/DE/PUBLIKATIONEN/_Anlagen/Downloads/Offshore/Standards/Standard-Investigation-impacts-offshore-wind-turbines-marine-environment_en.pdf?__blob=publicationFile&v=6.

6.5.2 Types of impacts

6.5.2.1 What are the main types of impacts?

Marine mammals (seals and cetaceans) may be affected by offshore wind farms in several ways. The primary focus for offshore wind projects to date has been on underwater noise effects, particularly from pile driving of wind-turbine foundations such as: (i) monopiles and (ii) jacket pin piles. Both of these types of pile driving can generate high levels of impulsive noise. However, a range of additional potential effects should be considered on a case-by-case basis, and may become important as understanding of their significance for marine mammals improves over time.

The types of impacts considered in appropriate assessments are summarised in Table 6-6. Appropriate assessments in particular need to consider if these (or other impacts) have the potential to influence the survival rate or reproductive success of individual marine mammals. This is an important consideration because the reproductive success of individuals can result in changes in the demographic parameters of a population, the outcome of which may be a measurable change in population size.

Table 6-6 Types of impacts on marine mammals during the project's lifecycle for offshore wind energy developments (based on traditional fixed wind turbines)[134]

Types of impacts	Project phase				
	Pre-construction	Construction	Operation	Decommissioning	Repowering
Habitat loss and degradation		X	X	X	X
Noise disturbance and displacement	X	X	X	X	X
Acoustic impairment (injuries from underwater noise)	X	X		X	X
Communication masking	X	X	X	X	X
Collision with vessels	X	X	X	X	X
Barrier effects		X	X	X	
Reduction of fishing pressure		X	X	X	
Water-quality changes (contaminants)		X	X	X	X
Electromagnetic field (EMF) effects on navigation			X	X	
Indirect effects	X	X	X	X	X
Reef effects			X	X	

Habitat loss

In a simple sense, construction of an offshore wind farm within a Natura 2000 site can be considered to represent loss of habitat equating at least to the footprint area taken up by the new infrastructure (including wind-turbine or substation foundations, scour protection, and cable protection).

In theory, habitat loss could also occur if wind-farm zones become important areas for marine mammals (e.g. foraging areas because of reef effects and/or reduced fishing or shipping pressure) and this benefit is lost upon decommissioning. However, there is no conclusive scientific evidence yet that wind-farm zones are indeed attractive for marine mammals.

[134] Although there is limited experience so far, it is expected that floating wind turbines are far less damaging in terms of: (i) habitat loss and degradation; (ii) noise disturbance; (iii) acoustic impairment; and (iv) communication masking. On the other hand, the 'reef effects' of floating wind turbines will be more limited.

Noise disturbance and displacement

Disturbance by underwater noise is typically considered in relation to activities such as pile driving and UXO detonations, both of which may generate sufficient noise to temporarily displace animals. High levels of noise from pile driving have the potential to affect animals over a large area (e.g. Thomsen *et al*., 2006; Nedwell *et al*., 2007; Diederichs *et al*., 2008; Carstensen *et al*., 2006; Bergström *et al*., 2014; Dähne *et al*., 2013). Brandt *et al*. (2011) investigated the behavioural responses of harbour porpoises to construction noise generated by monopile foundations driven into the seabed during construction of the offshore wind farm Horns Rev II in the Danish North Sea. They found a clear negative effect of pile driving on porpoise acoustic activity, which was reduced by 100% in the first hour after pile driving, and stayed below normal levels for 24-72 hours in the area within 2.6 km of the construction site. This period of reduced acoustic activity gradually decreased with increasing distance from the site of pile driving, and no negative effects were detected further than a mean distance of 17.8 km. The authors concluded that porpoise activity and possibly abundance were reduced over the entire 5 months of construction.

Studies at wind farms in the German North Sea have recorded large declines in porpoise detections close to the piling (> 90% decline at noise levels above 170 dB) with a diminishing effect the further away from the pile (25% decline at noise levels between 145 and 150 dB) (Brandt *et al*., 2016).

Information is also coming to light from an in-depth monitoring programme at the Beatrice offshore wind farm in Scotland. Monitoring of harbour-porpoise activity during pile-driving activity has indicated that porpoises are displaced from the immediate vicinity of the pile-driving activity, with a 50% probability of response occurring at approximately 7 km from the site of activity (Graham *et al*., 2017). This monitoring also indicated that the response diminished over the construction period and that porpoise activity recovered between pile-driving events.

The Swedish Environmental Agency focuses on vulnerable Baltic Sea harbour-porpoise populations. It considers that the behavioural effects, which may be perceived as milder than the physical effects, are potentially significant. This is because behavioural effects – like physical effects – can have fatal effects at both the individual level and at the population level. Scaring harbour porpoises away from their primary habitats entails a risk of damage caused partly by decreased energy intake and increased stress levels. Harbour porpoises have a limited ability to store energy, and they usually make up to 500 attempts to capture fish prey per hour (Wisniewska *et al*., 2016). This means that harbour porpoises are sensitive to disturbances, and their displacement to other secondary habitats over several weeks or months is expected to cause serious health effects (Forney *et al*., 2017). Chasing away this species from its primary habitats can result in significantly higher costs for ensuring its survival and motivating the animals to stay in the planned offshore wind-power area despite disturbances.

On the likely significant effects on harbour porpoises, it is important to add that most surveys that have been conducted so far were in areas such as the North Sea, where the conditions for harbour porpoises are much better than in the Baltic Sea. The investigated North Sea areas usually had strong porpoise populations with high abundance, i.e. conditions opposite to those found in the Baltic Sea. This also means that the conclusions of surveys cannot always be completely transferred to other marine areas. The local context is very important. The Baltic Sea porpoise population is small and has a poor conservation status. It is also heavily affected by by-catch, environmental toxicants, and underwater noise from activities other than wind power. On environmental toxicants, the Baltic Sea is also considerably more polluted than, for example, the North Sea. The level of pollution in the Baltic is such that the reproductive capacity of female porpoises has been reduced (Kesselring *et al*., 2017). Finally, the Baltic Sea has fewer good-quality habitats than the North Sea for the harbour porpoise to choose from. This means that the displacement of porpoises from a primary habitat in the Baltic Sea can have more serious consequences than their displacement from a primary habitat in the North Sea.

Next to noise from pile driving, noise from pre-construction and operations could also have an effect on sea life. Geophysical and geotechnical investigations are often used in connection with surveys for the construction of a wind farm at sea. These investigations involve high noise levels that can cause: (i) permanent and temporary hearing damage; (ii) escape/avoidance effects; and (iii) other behavioural effects. Some echo-sounders use frequencies within the hearing range of harbour porpoises and may disturb the species, which is highly dependent on acoustic communication for its survival. Continuous noise from vessels involved in regular maintenance can also cause disturbance.

Pile-driving noise can do serious physical harm to some animals, but it is a transitory operation that lasts for some months during the construction of the wind farm and then stops. On the other hand, the noise from operation of a wind farm is much less, but will continue at the site for many years. This could affect the behaviour of some species, possibly altering the ecosystem equilibrium of the site. Neither the initial nor the long-term noise effects on marine life of offshore wind-farm development are clearly understood yet. Nevertheless, it is clearly accepted that the negative effects exist, although the boundary levels (the points at which they become more or less damaging) are not clear (Castell J. *et al*., 2009).

Acoustic impairment

Injuries may result from the exposure of marine mammals to high levels of underwater noise. These can be injuries such as a shift in hearing threshold at one or more frequencies. At the extreme end of the scale, the injuries may be lethal. Sub-lethal injury may affect an individual's vital rates (i.e. their survival rate and their reproduction rate) and is therefore a potentially serious consequence. Temporary threshold shift (TTS) in hearing is regarded in this guidance as an extreme form of behavioural disturbance; permanent threshold shift (PTS) is considered to represent the lower limit for injury. PTS-onset thresholds are not derived empirically for ethical reasons. Instead, they are estimated based on extrapolating from TTS onset thresholds across the main, relevant, marine-mammal, functional-hearing species groups. For pulsed noise, such as piling, the NOAA (NMFS, 2018)[135] has set the onset of TTS at the lowest level that exceeds natural recorded variation in hearing sensitivity (6 dB), and assumes that PTS occurs from exposures resulting in 40 dB or more of TTS measured approximately 4 minutes after exposure. The use of PTS-onset thresholds does not mean that all animals will experience PTS; rather, PTS thresholds are used to indicate the range below which there is certainty that no PTS will occur. PTS onset is therefore a conservative indication of the numbers of animals potentially at risk of PTS, rather than a measure of those predicted to actually develop PTS. Pile driving and detonation of unexploded ordnance (UXO) are activities that generate sufficient energy to risk acoustic impairment. It is important that assessments give due regard to all such activities and that the potential for cumulative effects (for example between UXO detonations and piling in individual and separate projects) is not overlooked.

Additional potential effects, which should be considered on a case-by-case basis, are outlined below.

Communication masking

David (2006) found potential for pile-driving noise to mask strong vocalisations by bottlenose dolphin at 10-15 km and weak vocalisations at up to 40 km. Displacement effects in the dolphins (i.e. the dolphins moving away from the site of the pile driving) may override masking during construction. However, lower levels of noise, e.g. during wind-farm operation, could have significant consequences over a longer period of time if normal behaviours are compromised.

Collision with vessels

CEFAS (2009) and Bailey *et al*. (2014) have suggested that increased vessel traffic associated with offshore development increases the risk of vessel strikes, which could result in injury/mortality for marine mammals.

Most analyses of marine-mammal collisions with vessels are not related to wind energy development. Instead, they mostly concern maritime traffic in open-water shipping lanes, and involve larger species such as sperm and baleen whales. Most lethal strikes are understood to occur with ships 80 m or longer travelling at speeds of 14 knots or greater (Laist *et al*., 2001).

At one stage, there was concern that frequent findings of dead harbour seals and juvenile grey seals in the UK and other European waters with so-called spiral lacerations ('corkscrew' injuries) could have a man-made cause, such as interactions with ducted propellers used in many wind-farm service vessels (Bexton *et al*., 2012). However, evidence now suggests that these injuries are likely to have been caused by grey-seal predation (Brownlow *et al*., 2015).

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[135] https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance

The increased vessel-traffic load due to offshore wind energy activities is an important cumulative effect. It is especially significant in seas that are already under high shipping pressure like the Mediterranean or the North and Baltic seas.

Barrier effects

The concept of a barrier effect is based on the assumption that the presence of wind turbines and activities around a wind farm could present a barrier to the movement of certain marine-mammal species. This would be a more prolonged effect than: (i) temporary disturbance during construction/decommissioning; or (ii) discrete events during operation, such as maintenance works. For those species most commonly occurring near to existing offshore wind farms (e.g. harbour porpoises, harbour seals and grey seals) there appears to be no evidence of any barrier effect. Assessments have also discounted the possibility of multiple simultaneous piling events combining to represent a barrier to movement between one area and another (e.g. Smart Wind, 2015). However, for other species which might be encountered in new development areas such as the Mediterranean (e.g. the fin whale *Balaenoptera physalus*, the sperm whale *Physeter macrocephalus*, and Cuvier's beaked whale *Ziphius cavirostris*) there is no information on the potential for a barrier effect.

Water quality (contaminants)

Marine mammals are vulnerable to toxic contaminants which can bioaccumulate and be passed to offspring by nursing mothers (Bustamante *et al*., 2007). Most relevant bioaccumulating pollutants have now been phased out, and effects are largely the result of historical discharges. However, fat-soluble organochlorine compounds such as industrial polychlorinated biphenyls (PCBs) may be ingested through food and potentially lead to lower reproductive capacity and a suppressed immune system.

Any offshore marine development requires the use of various chemicals, such as diesel lubricants, oil lubricants, hydraulic fluids, and anti-fouling compounds (compounds that prevent the build-up of algae on marine infrastructure).

Changes to water quality can also occur through the mobilisation of suspended sediments. However, the relatively low sensitivity of marine mammals to suspended sediments, combined with the typically limited spatial and temporal scales of any effects, generally result in low-magnitude effects (e.g. Bergström *et al*., 2014)).

EMF

During operation, industry-standard AC and HVDC cables transmitting electricity will emit EMF, which can in turn induce electrical fields in the marine environment. Gill *et al*. (2005) speculated that magneto-sensitivity in cetaceans, likely associated with these animals' direction-finding ability, could potentially be affected by this phenomenon. There is no known evidence of such an effect occurring in practice, and this is currently not regarded as a likely significant effect for cetaceans.

Reef effects

A reef effect may be created when new structures are placed in marine waters. The colonisation (settlement of species on the structures) by algae, seaweed, etc. of the artificial 'reefs' (the 'reef effect') can result in the modification of surrounding natural habitats, including prey and its behaviour. This modification can include: (i) beneficial effects from reduced fishing; and (ii) more fish (prey) aggregations (see also Box 6-1).

There may be some potential for operational wind farms to have a positive effect for marine mammals and fish through: (i) habitat gain from the introduction of new hard substrates (foundations and scour protection) and/or; (ii) reduction/exclusion of fisheries activities (e.g. Bergström *et al*., 2014; Raoux *et al*., 2017; Scheidat *et al*., 2011). However, there is currently limited confidence about whether such an effect exists, and about its significance. More particularly, a long-term study (Teilmann and Carstensen, 2012) between 2001 and 2012 on one of the earlier offshore wind farms (Nysted in Danish waters in the western Baltic) reported that harbour-porpoise echo-location activity (as an indicator of porpoise presence) significantly declined within the wind farm area compared to baseline levels, and had not fully recovered by 2012. Echo-location activity within the wind farm did gradually increase, which could be indicative of a developing reef effect, but is not yet suggestive of a significant one. Conversely, Scheidat *et al*. (2011) reported a pronounced and significant increase in harbour-porpoise acoustic activity within the Egmond aan Zee wind energy development in the Netherlands. The authors noted the contrast with results at Nysted. They suggested that the effect of the Egmond aan Zee wind energy development is most likely net positive for marine mammals (because factors such as increased food availability and/or shelter outweigh any underwater noise from turbines and service ships). However, they stressed that the results should be generalised with caution and not be uncritically transferred to other wind energy developments in other habitats. This is because the balance between positive and negative factors may be different under different conditions. Determining whether marine mammals are benefiting from the presence of an offshore wind farm can only be investigated by long-term study, ideally including baseline surveys. However, making this determination is likely to be important in the planning of repowering or the decommissioning of projects at the end of their life.

Upon decommissioning there needs to be a balanced consideration of the advantages and disadvantages of leaving in place certain infrastructure, such as wind-turbine foundation bases and rock armour, which may confer benefits to marine mammals. This should be balanced against calls to remove such structures, which may arise from: (i) other conservation interests (e.g. if pre-existing habitats were of a different nature); and (ii) sea users, including fishing interests and those concerned with safety of navigation. Germany, for instance, has decided that decommissioning needs to involve the removal of all infrastructure, and this condition is included in the initial permit to build the infrastructure.

6.5.2.2 How is significance assessed?

The approach to determining significance focuses on relating the consequences of wind energy development activities (notably injury or disturbance) to individuals and population-level consequences.

A variety of factors can influence the significance of effects. These factors include biology, environment, plan design, and project design. Box 6-10 presents a summary of the factors typically taken into account in both: (i) the design of baseline-data collection methods; and (ii) an assessment of each factor’s significance.

Box 6-10 Factors determining the baseline collection methods and the assessment of significance in relation to offshore wind energy developments and marine mammals

Biological

- The marine-mammal functional-hearing group (Table 6-7).
- Proximity to breeding areas — Increased sensitivity is assumed for critical life-history events such as calving. This is reflected, for example, in stricter precautions on piling in certain Member States.

Environmental

- The underwater environment as it affects sound propagation. Underwater noise propagation is typically modelled. Optimal modelling should include input data describing bathymetry, seabed-sediment characteristics, and water-column properties affecting sound speed (temperature and salinity in addition to depth). This modelling should be validated by field surveys to confirm predictions (Farcas *et al*., 2016).
- Presence of geographical features which could exacerbate behavioural effects. For example, noise-generating activities around the entrance to a bay, through narrows, or in other spatially restricted areas could result in animals being unable to move away from high levels of noise, potentially increasing their risk of injury.

Plan design or project design

- Wind-turbine foundation design.
- Underwater-noise levels tend to increase as the pile diameter of driven foundations increases and greater hammer energies are applied.
- The installation of monopile foundations is likely to result in higher levels of underwater noise, but over a shorter period of time in total than the installation of foundations using jacket pin piles, where three or four smaller piles per foundation are typically used.
- Non-driven foundation solutions such as gravity bases, suction caissons, or floating turbines result in much lower noise levels. They are unlikely to result in significant underwater-noise effects.
- Ground type – This can affect the energy levels required for pile driving and the duration of piling activity.
- Vessel activity – The amount and type of vessels required during different project phases (including operation); their transit routes; and changes to existing marine traffic levels.

Table 6-7 Marine-mammal functional-hearing groups and hearing ranges (adapted from Southall, 2007)

Functional-hearing group	Functional-hearing range*
Low-frequency cetaceans+ (baleen whales)	7 Hz to 30 kHz
Mid-frequency cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
High-frequency cetaceans (true porpoises)	180 Hz to 200 kHz
Phocid pinnipeds (true seals)	75 Hz to 100 kHz

* Represents frequency band of hearing for entire group as a composite (i.e. all species within the group), where individual species' hearing ranges are typically not as broad.

+ Estimated hearing range for low-frequency cetaceans is based on behavioural studies, recorded vocalisations and inner ear.

The risk of auditory injury to marine mammals (i.e. PTS or greater effects) has been evaluated using a range of thresholds based on available audiograms. For example, criteria provided by Southall *et al*. (2007) have been commonly used. NMFS (2018), often referred to as the NOAA guidance/thresholds, currently represent the most up-to-date guidelines for determining PTS for both impulsive noise (e.g. from pile driving) and non-impulsive noise (e.g. from dredging or vessel operation). The risk of injury is based on two criteria: cumulative sound-exposure level (SELcum) and peak sound-pressure level (peak SPL) (see Table 6-8). To assess the SELcum criterion, predictions of received sound level are frequency weighted to reflect: (i) the hearing sensitivity of the functional-hearing group of each marine-mammal species; and (ii) sound exposure determined over a 24-hour period of activity. The peak SPL criterion is compared to the unweighted received sound level. Exceedance of either threshold is considered to represent a likelihood of PTS injury.

Table 6-8 NOAA (NMFS, 2018) PTS thresholds for pulsed noise

Hearing group	PTS threshold	
	SELcum [dB re 1 μPa^2 s] *	**Peak SPL [dB re 1 μPa] unweighted**
Low-frequency cetaceans	183	219
Mid-frequency cetaceans	185	230
High-frequency cetaceans	155	202
Phocids	185	218

* weighted according to NMFS (2016) audiogram-weighting functions for each hearing group.

The behavioural effects of wind-farm construction may be investigated using a dose-response curve. Where possible, this curve should provide species-specific empirical evidence from the most appropriate available monitoring data. The use of population models to assess the population consequences of disturbance effects is also being developed (see Case Study 6-3).

Case Study 6-3 Marine-mammal population models

The population consequences of sub-lethal effects, such as disturbance associated with wind-turbine foundation piling, may be investigated using predictive modelling or population-viability analysis. Two such approaches are iPCoD and DEPONS, discussed in the bullet points below.

- DEPONS (Disturbance Effects on the harbour-porpoise population Of the North Sea) is a research programme led by the National Centre for Environment and Energy (DCE) at Aarhus University. The programme has released a freely available model to simulate how harbour-porpoise population dynamics are affected by pile-driving noise associated with the construction of offshore wind farms. DEPONS is built on an individual-based model of harbour-porpoise movement and energetics developed by Jacob Nabe-Nielsen and colleagues (Nabe-Nielsen *et al.,* 2011; Nabe-Nielsen *et al.,* 2013; Nabe-Nielsen *et al.,* 2014).
- iPCoD (interim Population Consequences Of Disturbance) is a framework for investigating the effects of noise, especially from offshore wind-farm piling (Harwood *et al*., 2013; King *et al*., 2015). The model takes the number of marine mammals predicted to be subject to disturbance and/or PTS injury, and predicts the future population trajectory based on consequences reached by an expert elicitation process. In due course, it is hoped that empirical data will be available to replace expert judgement. The framework can be applied to several species including harbour porpoises, grey seals, harbour seals, bottlenose dolphins and minke whales. Although iPCoD relies on some strong assumptions and on expert opinion. Its strengths include being transparent, auditable and quantitative. One of the main strengths of iPCoD may be its ability to assess the cumulative impact of several offshore wind energy developments.

Further information on population models used in marine-mammal impact assessment is provided in Sparling *et al*. (2017).

Source:
DEPONS model available at: https://zenodo.org/record/556455#.XCz0GGj7S70.
iPCoD model available at: http://www.smruconsulting.com/products-tools/pcod/ipcod/.

Case Study 6-4 Assessing the impact of noise from pile driving on marine mammals, Germany

Germany's Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) has issued two technical standards for environmental investigations of the effect of noise on marine mammals. The standard investigation of the effects of offshore wind turbines on the marine environment (StUK 4) is separated into:
(i) a standard with measuring instructions for underwater sound monitoring; and
(ii) a standard for offshore wind parks with predictions for underwater sound and minimum requirements on documentation.

The strategy followed by the authorities to prevent any significant effects of pile driving on harbour porpoises is that of technical mitigation and reduction of noise at the source. According to the German regulation, the threshold level for potential effects on harbour porpoises is up to 160 dB SEL (sound-exposure level) at a 750 m distance from the piling location.

According to the 2013 protection plan for harbour porpoises in the German exclusive economic zone of the North Sea, construction work must be coordinated in a way that a minimal effect on individuals or on population levels of harbour porpoise is expected. At all times, no more than 10% of nature-conservation sites are allowed to be disturbed by underwater sound. This rule is based on the general approach set by the federal agency, which states that when an area of more than 1% is lost, the effect is considered significant. However, since piling is a temporary activity, a disturbance area of 10% is considered to be acceptable[136].

For the Natura 2000 area Sylt Outer Reef, there is one exception to the rule. In the period from April to August, no more than 1% of this area may be disturbed, because it is presumably a breeding area for the harbour porpoise.

Source:
https://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/Strategie_Positionspapiere/schallschutzkonzept_BMU.pdf

Case Study 6-5 Permit conditions related to harbour porpoises for an offshore wind farm in Sweden

A wind energy company had applied for a permit to build an offshore wind farm containing a maximum of 50 wind-power turbines in the county of Halland. Two adjacent Natura 2000 sites, Stora Middelgrund och Röde bank (SE0510186) and Lilla Middelgrund (SE0510126), are situated as close as 20 km from the wind-farm area. Harbour porpoise occur in relatively large numbers in this part of the Kattegatt. Stora Middelgrund is one of the most important reproduction areas for the Belt Sea porpoise population. Lilla Middelgrund also supports high numbers of harbour porpoise. There is an area of particular importance for the harbour porpoise as close as 10 km from the wind-farm area.

In 2015, the Swedish Land and Environmental Court of Appeal ruled[137] that the strict protection of species provisions was applicable. It also found – as the Swedish Land and Environmental Court had found earlier – that the harbour porpoises' slow reproduction rate and long generational turn-over time makes every disturbance of individuals significant for the conservation status of the whole population.

The Court ruled that the Stora Middelgrund och Röde bank area, and the particularly important area about 10 km from the wind farm (where sexually mature females spend 50% of their time), would not be subject to noise-disturbance levels

136 https://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/Strategie_Positionspapiere/schallschutzkonzept_BMU.pdf
137 Judgment of the 2015-12-08, case M 6960-14, available at https://databas.infosoc.se/rattsfall/30866/fulltext

causing displacement of harbour porpoise. On that basis, the Court ruled that as long as the local effects only occur within a ten-kilometre radius of the wind-farm area, there is no significant risk that the Natura 2000 areas will be affected.

The wind-farm company received a permit to build the wind farm under certain conditions. One condition was that the company had to ascertain that no harbour porpoise would be present within a 750 m radius of noisy activities of a certain level during both the construction and the dismantling phases of the project.

Source: Swedish Agency for Marine and Water Management

Box 6-11 summarises some of the uncertainties and challenges encountered in the assessment of likely significant effects on marine mammals. These uncertainties and challenges may mean that additional baseline-data collection is required or that the precautionary principle should be applied.

Box 6-11 Key challenges in assessing likely significant effects and marine mammals

All effects

- The drivers of seasonal and inter-annual variation in the distribution of marine mammals.
- The relative importance of different sea areas, for example: (i) for foraging; (ii) as migration corridors; and (iii) for breeding (mating and/or calving).

Underwater noise

- The spatial extent of disturbance and the numbers of animals affected.
- The mechanism(s) underlying marine-mammal response to noise.
- The relative importance of noise from vessels, pile driving, acoustic deterrents, and other sources in disturbing and displacing marine mammals.

Variation in response due to habitat quality, seasonality and construction techniques

- The effects of disturbance or injury (PTS) on marine-mammal vital rates (e.g. survival and reproduction).
- The lack of empirical data for some species. For example, there appear to be no studies of the behavioural response of the minke whale to pulsed sounds (Harwood & King, 2017).
- Underwater-noise levels from operating wind turbines have been considered unlikely to significantly affect marine mammals (Bailey *et al*., 2014). However, there is some uncertainty about the likely noise levels of newer and much larger turbines (e.g. 10 MW+). Assessments should avoid assuming that noise levels will necessarily remain below levels of concern.
- There is uncertainty about the interplay between the absolute magnitude of underwater noise and the duration of the effect. For example, a wind farm based on monopile foundations will take less time (total time spent pile driving) to install than the same wind farm based on jacket foundations, but absolute noise levels will likely be louder for (larger) monopile foundations. Both scenarios should be evaluated, and the worst case in terms of marine mammals affected (i.e. the number of animals injured and/or displaced) taken forward for assessment.
- Over distance, impulsive noise transitions to become more continuous in nature. The PTS-effect thresholds for continuous noise are higher (i.e. require greater sound levels to have an effect) than for impulsive sound. However, the range at which it is appropriate to apply continuous-noise thresholds for activities such as pile driving or UXO detonations is unclear and is likely to vary depending on site-specific conditions.

Displacement

- There are uncertainties about the importance of displacement on marine-mammal individuals and populations, i.e. the ecological consequences (see Case Study 6-3).
- There are gaps in knowledge on how Baltic Sea harbour porpoises are affected by the operational phase. There are very few studies on harbour porpoises. The studies that have been conducted have generated results that are not necessarily applicable to Baltic Sea conditions (comment by Swedish Agency for Marine and Water Management, 2019).
- Although most studies have focused on pile-driving noise, Brandt *et al*. (2018) also describe a decline in porpoise detections in the vicinity of construction sites several hours before piling. This is possibly due to an increase in activities (e.g. vessel traffic) around construction, also facilitated by better underwater sound transmission during the calm weather conditions during which piling occurs. Such an effect would potentially call into question the use of acoustic deterrent devices if these add unnecessarily to underwater-noise levels. However, this issue requires further research.

Masking

- There is limited information on masking, which is a potentially significant effect if the routine use of sound by marine mammals is compromised by underwater noise.

Collision with vessels

- There is limited information on collisions between marine mammals and vessels in connection with the construction and operation of offshore wind energy developments.

EMF

- Bergström *et al*. (2014) suggested that on the basis of the very scant empirical information available, no significant effects have been shown to date of EMF on marine mammals (their study covered four species: harbour porpoise, harbour seal, grey seal and ringed seal).

Barrier effects

- The concept of a barrier effect is based on the assumption that the presence of wind turbines and activities around a wind farm could present a barrier to the movement of certain marine-mammal species. While this effect is quite well understood for some marine-mammal species, for other species the evidence for any barrier is less clear.

Reef effects

- There have been hypotheses about the potential for operational wind farms to have a positive effect for marine mammals, through: (i) habitat gain for the introduction of new hard substrates (foundations and scour protection); and/or (ii) reduction/exclusion of fisheries activities (e.g. Bergström *et al*., 2014; Raoux *et al*., 2017; Scheidat *et al*., 2011). However, there is currently limited confidence about whether such an effect exists, and its significance.

6.5.3 Possible mitigation measures

6.5.3.1 Introduction

This chapter provides an overview of possible mitigation measures that have been proposed or applied with reference to offshore wind energy developments and marine mammals.

The following measures are discussed:

a) exclusion of specific areas (macro-siting);
b) avoidance of sensitive periods such as the breeding season (scheduling);
c) measures related to the type of turbine foundation (low-noise foundations);
d) noise-restriction measures to reduce the levels of underwater noise emitted during construction;
e) surveillance (visual and acoustic) of marine-mammal presence in exclusion areas;
f) measures to actively deter animals away from such areas.

The measures described focus on pile driving and detonation of UXO, which are the most important noise-generating activities associated with offshore wind-farm development. For the most part, these activities are restricted to the construction phase, but they could also potentially be relevant to repowering. The absence of measures for development phases and activities other than pile driving/UXO does not mean that these other phases and activities should be ignored. Significant effects are generally not anticipated for activities such as the pre-construction geophysical survey. Nevertheless, best-practice approaches should be followed to: (i) minimise unnecessary emission of acoustic energy; (ii) reduce the risk of other pollution; and (iii) reduce the risk of collisions with marine mammals etc.

Box 6-12 presents the mitigation framework for pile driving, drilling and dredging, presented by the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic area (ACCOBAMS).

Box 6-12 Mitigation framework for pile driving, drilling and dredging (ACCOBAMS, 2019)

Planning phase (expected outcomes of the EIA)

Review the presence of cetaceans in the candidate periods for the works, and carry out – or fund – research where information is non-existent or inadequate.
Select periods with low biological sensitivity.
Use sound-propagation modelling results, verified in the field, to decide on the boundaries of the exclusion zone.
Plan the lowest practicable source power.
Consider alternative technologies (See 6.5.3.4).
Plan noise-mitigation technologies if no alternatives are possible (See also 6.5.3.5).

Real-time mitigation practices

Use acoustic mitigation devices before beginning the work (see 6.5.3.5).
Use the 'soft start' protocol (see 6.5.3.5).
Use the visual and acoustic monitoring protocol (see 6.5.3.6).

Post activity

Detailed reporting of real-time mitigation.

Source: ACCOBAMS, 2019. Available at https://accobams.org/wp-content/uploads/2019/04/MOP7.Doc31Rev1_Methodological-Guide-Noise.pdf

6.5.3.2 Macro-siting

Appropriate siting, and a consideration of area-exclusion in recognition of the presence of habitats that are critical to marine mammals, makes it possible to avoid significant effects on marine mammals.

Based on the example of the Birdlife International process for determining "important bird and biodiversity areas" (IBAs), the International Union for the Conservation of Nature (IUCN) Joint SSC/WCPA Marine Mammal Protected Areas Task Force identified important marine-mammal areas (IMMA)[138]. IMMAs are defined as discrete portions of habitat, important to marine-mammal species that have the potential to be delineated and managed for conservation. Knowledge of areas that are important for marine mammals will facilitate the balancing of human uses of the sea, such as offshore wind energy developments, with the imperative of conserving marine biodiversity.

6.5.3.3 Scheduling: Avoiding, reducing or phasing activities during ecologically sensitive periods

Scheduling involves avoiding or suspending construction activities (on pile driving and detonation of UXO) during sensitive periods of the biological cycles of species (e.g. in breeding or feeding seasons). Scheduling is considered a very effective measure as it can prevent the disturbance of species from noise and other effects during those periods. However, it should be noted that seasonal restrictions could be hard to implement for some species with long sensitive periods. For example, the harbour porpoises in the North-Atlantic mate in July/August and give birth to their calves in May/June the following year. Thereafter, the calves are completely dependent on their mothers for milk for about 8-10 months. During this time, if mother and calf are separated, this can very easily lead to the calf's death. There are therefore no 'safe' periods for harbour porpoises. In such species, simply avoiding breeding seasons is not enough to avoid a negative effect. By contrast, scheduling would be appropriate in other areas of Europe's seas, such as the Mediterranean. This is because some of the Mediterranean's marine mammals, such as fin whales *Balaenoptera physalus*, are known to be sensitive to man-made disturbance but display marked seasonal distributional patterns[139].

6.5.3.4 Infrastructure design: turbine foundations

Infrastructure-design measures aim at avoiding acoustic impairment and reducing disturbance/displacement effects. High levels of underwater noise are associated with the pile driving of monopile and jacket-pin-pile foundations. Alternative foundations that do not result in such high noise levels are available, and have been used by a number of projects.

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[138] https://www.marinemammalhabitat.org/immas/imma-eatlas/
[139] https://www.sciencedirect.com/bookseries/advances-in-marine-biology/vol/75/suppl/C

Piled foundations dominate existing offshore wind farms with both monopiles and jackets. Jacket pin piles use several smaller pin-piles anchoring each foundation. However, the world's first offshore wind farm, Vindeby in Denmark, was constructed using gravity bases. Several other projects also subsequently used gravity bases. Another foundation type which avoids the requirement to employ pile driving is the suction bucket or caisson, which has been used in other offshore industries for several decades. The suction bucket or caisson has recently been trialled in the offshore wind industry, and used in several smaller installations, such as for meteorological masts on Dogger Bank in the North Sea. More recently, the established technique of floating foundations has been trialled in the wind-farm industry in deployments off the coasts of Scotland (Kincardine and Hywind), France (Floatgen) and Portugal (Windfloat Atlantic). This technology opens up the possibility of locating wind farms in deeper-water sites and achieving substantially reduced underwater-noise emissions during construction.

Installations of gravity bases, caissons, or floating foundations are not without underwater-noise emissions. This is because there may be a need for seabed preparations involving dredging-type activity, and associated vessel noise is unavoidable. However, impulsive noise is absent from these methods (unless associated with UXO clearance), and noise levels are understood to be very low (relatively speaking) for all such alternative-foundation designs.

There is no doubt that the noise reduction achieved through use of non-piled foundations is advantageous for marine mammals. However, there will be practical and commercial considerations for projects using non-piled foundations, and it is also necessary to consider the inadvertent consequences of decisions to use them. For example, gravity bases have a larger footprint than any driven foundation. They therefore have the potential to have greater effects on benthic habitats, both directly through habitat loss and via hydrodynamic changes. Such effects must be carefully evaluated in appropriate assessments where relevant.

6.5.3.5 Noise reduction: various engineering approaches

'Soft start' and other noise-mitigation systems (NMS) can be applied to reduce disturbance and displacement and to avoid the acoustic impairment of marine mammals.

A soft start to piling aims at reducing the levels of underwater noise emitted during construction. It generally means a gradual ramp up in hammer energy and blow frequency over 20 minutes or more. Soft start is sometimes described as a mitigation measure in project assessments. It is typically included on a 'common sense' basis (the rationale is to allow sufficient time for animals to leave the immediate vicinity and avoid harmful noise levels) even though no studies have systematically confirmed the effectiveness of this method (Bailey et al., 2014). Soft start is also required from an engineering perspective, at least for initial driving, until the piles become stabilised and greater energy levels are required to achieve ground penetration. In these guidelines, soft start and ramp up are considered to be effectively standard, built-in processes. If the approach goes beyond that required from an engineering perspective, it may be considered a mitigation measure if an assessment is initially made without the measure in place. In all cases, such measures should be carefully specified and assessed. This is particularly the case when dealing with small and very sensitive populations, such as the Baltic Sea harbour-porpoise populations. It is paramount that all mitigation measures used are proven effective and are not in themselves harmful or problematic in any way.

But although soft start and piling ramp up may reduce the risk of auditory injuries, there is some concern that it could increase the magnitude of disturbance/displacement effects. This could happen if the total duration of pile driving, and potentially the cumulative energy input from piling, is increased (Verfuss et al., 2016). However, this risk could be limited by imposing time limits (e.g. like in Germany) and using acoustic deterrents.

Two examples of NMS are bubble curtains and hydraulic hammers. A bubble curtain consists of a hose fitted with nozzle openings that is laid out on the sea floor around the pile at a distance of more than 50 m from the piling site. Air is fed into the nozzle hose with compressors and discharged via the nozzles. This causes a continuously rising curtain of air bubbles around the installation site, which reduces noise due to scattering and absorption effects. Hydraulic hammers have an acoustically decoupled, double-wall isolation casing with an air-filled interspace[140].

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[140] More information can be retrieved from a German workshop in 2018, see https://www.bfn.de/en/activities/marine-nature-conservation/conferences/noise-mitigation-2018.html

Box 6-13 Examining effects on harbour porpoises in German waters

Brandt *et al*. (2018) examined the effects on harbour porpoises of first-generation active NMS applied in the construction phase of 6 out of 7 wind farms in the German Bight between 2010 and 2013. During wind-farm construction projects after 2013, noise levels at 750 m distance with the application of NMS usually fell below the required threshold of 160 dB. The authors describe a clear gradient in the decline of porpoise detections after piling, depending on noise level and distance to piling. Piling events with NMS decreased the distance at which no effect was measured from 17 km to 14 km, leading the authors to conclude that the application of NMS led to a lower decline of porpoise detections over all distances. The authors recommended further investigations, as NMS are being further developed and improved. Nevertheless, this initial evidence (together with other publications such as: (i) Nehls *et al*. (2015) for piling; and (ii) Koschinski and Kock (2009) for UXO (Koschinski & Kock reported that the area of disturbance of harbour porpoise can be reduced by around 90%)) suggest that noise-reduction techniques currently represent best practice where there is concern about effects to marine mammals if piling or UXO detonation is required.

Dahne *et al*. (2017) reported that two bubble curtains attenuated noise by between 7 and 10 dB when used separately and by 12 dB when used together. Attenuation was most pronounced above 1 kHz, where the pile-driving noise at larger distances was comparable to – or lower than – ambient noise. This suggests that noise regulation should be based on frequency-weighted sound levels in addition to broadband levels, to ensure that mitigation measures are effective in reducing effects on animals and not only in fulfilling legal requirements.

The above advances in noise reduction technology in German waters have been driven by the imperative of meeting national regulatory requirements (BMU, 2013) known as the 'schallschutz concept' or noise-mitigation concept for the German EEZ of the North Sea. These apply maximum threshold levels of 160 dB SEL and 190 dB Lpeak at a 750 m distance from the piling location (prohibition of injury and killing). They further require that not more than 10% of the German EEZ of the North Sea is affected by sound exposure level ≥ 140 dB (SEL) (prohibition of disturbance) and that additionally between May and August not more than 1% of the main concentration area for porpoise is affected by sound exposure level ≥ 140 dB (SEL) (prohibition of disturbance).

Furthermore, the pile driving time for monopiles is limited to 180 min and for jacket piles to 140 min per pile, both including deterrent use (See also Case Study 6-6).

Other noise-mitigation measures are set out in the bullet points below (ACCOBAMS, 2019).

- Hydro sound dampers: fishing nets attached to small balloons filled with gas and foam that are tuned to resonant frequencies.
- Cofferdams: a rigid, steel tube surrounding the pile. Once the pile is stabbed into the cofferdam, the water is pumped out.
- IHC/NMS: a double layered screen filled with air. Between the pile and screen there is a multi-level and multi-size bubble-injection system.
- Tuneable resonator system: this noise-abatement system, inspired by Helmholtz resonators, uses a simple collapsible framework containing arrays of acoustic resonators with two fluids (air and water).

6.5.3.6 Surveillance of exclusion zones: visual and acoustic observations

The demarcation and surveillance of exclusion zones can reduce disturbance and displacement effects, and avoid the acoustic impairment of marine mammals.

Surveillance is a commonly implemented measure, and involves marine-mammal observers being tasked to visually – and often also acoustically – monitor a zone around the noise source for at least 30 minutes. This is to ensure, as far as possible, the absence of marine mammals (and possibly other protected species such as sea turtles) before beginning piling, UXO detonation, etc. This zone may be demarcated by a fixed distance from the source (e.g. 500 m), or based on the expected received sound levels. In areas where water depths in the exclusion zone exceed 200 m, the observation time should be at least 120 minutes to increase the probability that deep-diving species are detected (ACCOBAMS, 2007). The exclusion zone is aimed at reducing near-field noise exposure and protecting animals from direct physical harm. It is unlikely to be effective in mitigating behavioural responses over greater distances, since disturbance in more remote areas is still likely to occur.

It is important to note that effectiveness may be limited by: (i) adverse weather conditions and darkness (both of which restrict visual observation); (ii) factors such as the limited propagation of vocalisations of some species such as the harbour porpoise (typically not more than around 200 m for this species); and (iii) the general absence of vocalisations in pinniped species of relevance to most offshore wind energy assessments.

6.5.3.7 Deterrents: acoustic deterrent devices

Deterrent measures can reduce disturbance and displacement effects and avoid acoustic impairment.

Seal-scaring devices have long been used to displace seals from fish farms. However they have also been recognised as helpful in reducing the risk of injuries to seals and cetaceans during the construction of wind energy developments. In the construction of wind energy developments, seal-scaring devices are generally termed 'acoustic deterrent devices' or 'acoustic mitigation devices'. A seal scarer produces underwater noise that is unpleasant to the target species but not injurious, and therefore deters them from approaching any closer. They can potentially be used to temporarily displace individuals from areas where harmful levels of noise may occur due to activities such as foundation piling or UXO detonations (See also Case Study 6-6).

Dahne *et al*. (2017) describe the use of an acoustic deterrent device to protect harbour porpoises from losing their hearing due to pile-driving noise. The authors noted strong reaction to the seal scarer, and raised concern that it may surpass the reactions to the pile-driving noise itself when operating with bubble curtains. This suggests that there are grounds for a re-evaluation of the specifications of such acoustic deterrent devices. Similar concerns was raised by Verfuss *et al*. (2016).

Acoustic deterrent devices do not reduce behavioural effects, but only reduce the directly physical effects. This is not sufficient when trying to mitigate negative effects in threatened populations, such as the Belt Sea or Baltic Sea harbour-porpoise population. It is certainly not sufficient when the outcome is displacement from primary habitats to secondary habitats. However, pinger devices[141] do not guarantee that all porpoises will vacate the affected area, so the use of pingers does not guarantee that individual porpoises will avoid being physically affected by the construction noise.

Therefore, measures should clearly not add unnecessarily to disturbance/displacement effects, and the use of acoustic deterrent devices must be proportionate and duly justified in light of such evidence.

Case Study 6-6 Mitigation of noise effects from pile driving on marine mammals, Germany

The Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) has issued several technical standards on the effect of noise on marine mammals and supporting studies. The BSH's standard investigation of the effects of offshore wind turbines on the marine environment (StUK 4) contains four such standards:

- instructions for underwater-noise monitoring;
- offshore wind parks – predictions for underwater noise, minimum requirements for documentation;
- specifications for the quantitative determination of the effectiveness of noise control systems;
- a study to evaluate the calibration of C-PODS devices (devices that listen to sounds made by sea mammals) used to detect harbour porpoises (only available in German).

After permit approval by the authorities, offshore wind energy operators are obliged to develop and present a noise-mitigation plan, taking into consideration: (i) the most advanced methods for technical mitigation of noise; (ii) the site and project characteristics; and (iii) results from R&D and previous developments. Six months before construction starts, a noise-mitigation plan with a detailed description of the implementation of noise mitigation measures must be presented to the authorities.

The following noise-mitigation techniques are standard procedures in Germany[142]

[141] Pingers are devices that alert cetaceans to the presence of nets (they are mostly used with driftnets), as opposed to deterrents that cause the animals' avoidance because they are unpleasant.
[142] https://www.bsh.de/DE/PUBLIKATIONEN/_Anlagen/Downloads/Projekte/Erfahrungsbericht-Rammschall.html

- Before piling starts, there is a requirement to actively move harbour porpoise away from the area of works, even if that means a temporary disturbance.
- Developers cannot start construction if there are porpoise within 750 m and only after they have proven that the deterrence measure(s) have worked using a C-POD (this C-POD detects the vocalisations (‘clicks’) that harbour porpoises make).
- Deterrence of the porpoises is performed using two different systems (seal scarers or similar).
- It is recognised that there is a risk of unnecessary disturbance being introduced into the marine environment by these deterrent devices.
- The piling must start with a gradual increase of noise intensity so that the mammals can become aware of the works and move away from the construction area before noise levels threaten injury.
- A noise level of 160 dB SEL and 190 dB Lpeak may not be exceeded within 750 m of the sound source during the construction phase.
- The effective time for driving a monopile to target depth may not exceed 180 min and for jacket piles 140 min per pile.
- Use of a (double) bubble curtain. This is a system of perforated hoses or pipes in a circle on the seabed around the pile driving site. The air rising from the holes forms a curtain of ascending bubbles in the water that reflects or muffles the propagated sound.

Additionally, as summarised by Verfuss *et al*. (2016), no more than 10% of the German North Sea EEZ is to be impacted by piling noise from all wind farm projects at a time. For calculating the total cumulative area impacted, the impact areas for all projects currently undergoing foundation construction must be combined. The 10% spatial threshold was based on the assumption that the behavioural disturbance caused by pile driving is temporary, and that porpoises will eventually re-enter the area from which they were displaced. However, a 1% spatial threshold is applied: (i) to areas with high porpoise density; and (ii) during the breeding and mating season from May to August, when disturbance may have a greater effect on harbour-porpoise vital rates. For Special Areas of Conservation (SACs), these spatial thresholds are measured against the size of the protection area rather than the whole EEZ (i.e. in the North Sea less than 10% of an SAC can be impacted by piling noise, while from May to August, only less than 1% can be impacted).

Source:
https://www.bsh.de/DE/PUBLIKATIONEN/_Anlagen/Downloads/Offshore/Standards/Standard-Investigation-impacts-offshore-wind-turbines-marine-environment_en.pdf?__blob=publicationFile&v=6https://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/Strategie_Positionspapiere/schallschutzkonzept_BMU.pdf

6.6 Other species

6.6.1 Introduction

Potential effects on plants, algae and invertebrates are generally considered in relation to their habitats (Chapter 6.2). Conversely, the sensitivity of marine habitats is often described partly in relation to factors such as the resistance and resilience of associated and typical species. However, further information is included in this chapter because effects on these receptors may have consequences for groups such as marine mammals or seabirds if, for example, their foraging is significantly affected.

This chapter also provides information on likely significant effects on bats where these effects occur in the marine environment.

6.6.2 Types of impacts

6.6.2.1 Plants and algae

The only plant species specifically associated with Annex I habitat types are *Zostera marina*, *Zostera noltii*, *Cymodocea nodosa* and *Posidonia oceanica* (Posidonia beds, *Posidonion oceanicae)*[143].

Other seagrass species are potentially vulnerable to habitat loss and disturbance effects if they are present in close proximity to offshore wind farms. Their requirement for shallow, sunlit waters means that seagrass interactions with offshore wind energy projects may be more likely to occur with export cable routes than wind-

[143] See EU Habitats Interpretation Manual: https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf

farm array areas. However, at the Middelgrunden shallow offshore wind farm in the Öresund strait in Denmark, seagrass beds (*Zostera marina*) were present before wind-farm construction, Monitoring of these beds revealed that, 3 years after installation of the wind turbines, seagrass coverage was not affected, indicating no adverse effect due to wind-farm construction (including dredging and the deployment of gravity bases) (Hammar *et al*., 2016).

Marine algae are commonly recorded as colonising new structures provided by wind-turbine foundations, in particular in the North Sea where intertidal hard substrata are rare. Equivalent habitats have been provided by the offshore oil and gas industry, but wind-farm foundations are more numerous (Dannheim et al., 2019). Such colonisation contributes to increased structural and biological diversity, potentially resulting in a reef effect (see also Box 6-1) which is further considered below in relation to colonisation by invertebrates.

6.6.2.2 Invertebrates

For marine invertebrates, infrastructure for wind energy developments introduces new hard substrata above and below the water line to which they can attach. This reef effect may in certain circumstances increase diversity, although some studies have also suggested a risk that it may contribute to the spread of non-native invasive species (Inger *et al*., 2009).

However, regardless of the net biodiversity gain, a change in habitat or species communities may still adversely affect the conservation objectives of the Natura 2000 site in question. Offshore wind energy developments must therefore always be subject to an appropriate assessment.

Temperature increase around cables has also attracted attention, with reference to the effect on benthos. Operation of submarine power cabling will generate heat, which warms local sediments. The degree of warming depends on the characteristic of the cables, the power carried, the burial depth of the cable, and the characteristics of the sediment (OSPAR, 2009). Any heat is rapidly carried away by the seawater. As a result, effects in shallow sediments, where cables are buried to 1 m or more and where there is efficient heat exchange with the overlying waterbody will be negligible. This means that epifauna, and shallow infauna in the first few centimetres of sediments, will not be exposed to significant temperature change. Most benthic animals dwell in the upper 5-10 cm of the seabed in open waters and the top 15 cm of the seabed in intertidal areas where temperature increases will be small, provided that the burial depth of the cable is sufficient (Petersen & Malm, 2006; Meissner & Sordyl, 2006). Some animals, such as Norway lobster, do burrow deeper into the seabed, although the total habitat area subject to heating is likely to be very limited.

6.6.2.3 Bats

The UNEP/EUROBATS guidelines mentioned in Chapter 0 (Rodrigues *et al*., 2015) also apply to offshore wind farms. However, there are considerable additional challenges and uncertainties in the offshore environment which are set out below. Information provided in this chapter is relevant to bat species listed under Annex II and Annex IV, with an additional focus on migratory species that are exposed to greater risk (notably Nathusius' pipistrelle in the North Sea, not listed on Annex II; see Lagerveld *et al*., 2017).

As is the case with onshore installations, baseline data to support an appropriate assessment should be collected using: (i) best-practice survey methods, as described in Rodrigues *et al*. (2015); and (ii) any relevant national or regional guidance. Surveys should consider a wider zone of influence, covering both the proposed onshore and offshore infrastructure, and potential migration routes. Typical baseline-survey requirements are summarised in Box 6-14.

Box 6-14 Examples of offshore baseline surveys (adapted from Rodrigues *et al*., 2015)

- Use of manual bat detectors on transect surveys or point surveys based on boats, including regular night-time ferry crossings through or near a plan or project site.
- Use of automated detectors on offshore infrastructure where possible (e.g. oil rigs, meteorological masts, buoys etc.).
- Use of existing radar where available.

Surveys need to take into account the full cycle of bat activity throughout the year, and provide information on roosting (breeding, mating/swarming, hibernation), foraging, and commuting. It is especially important for surveys of offshore proposals to identify the likelihood of bat migration routes interacting with the offshore infrastructure.

The main types of impacts on bats from onshore wind energy developments are summarised in Box 5-6 and Table 5-4. For offshore wind energy developments, the risk of mortality through direct collision or barotrauma has an additional transboundary dimension, as bats may be resident hundreds of kilometres from the offshore infrastructure in question.

Box 6-15 summarises the challenges and uncertainties encountered in identifying and assessing significant effects on bats. These challenges and uncertainties may require additional baseline data collection or the application of the precautionary principle. To assess the effects of potential added mortality at sea, it is necessary to know – or be able to estimate – the population size of bats, including the portion of the population crossing the sea. Potentially relevant species are Nathusius' pipistrelle (*Pipistrellus nathusii*), the common noctule (*Nyctalus noctula*), and the particoloured bat (*Vespertilio murinus*). One study (Limpens *et al*., 2017)[144] attempted to develop a prototype estimator for migrating populations of bats. The estimator was only applied to Nathusius' pipistrelle because of the limited data. Although the model produced a preliminary estimate for bats crossing the southern North Sea of roughly 40,000 individuals, the range was between 100 and 1,000,000 individuals (several orders of magnitude) – and the source populations remain unknown.

Box 6-15 Key challenges in assessing likely significant effects and bats

Migration

- Empirical data on offshore migratory flight activity is limited. Even where data are collected, this is usually at too small a scale to detect migrating bats at all.

Collision

- There are limited empirical data on: (i) offshore migratory flight activity; or (ii) evidence of at-sea collisions and barotrauma – methods of data collection are still developing (e.g. Lagerveld *et al*., 2017).
- There are significant challenges to monitoring collisions at sea.

Barrier effect

- The cumulative barrier effect to long-distance migrants of avoiding multiple, offshore wind-power arrays along the course of their migration route remains unstudied (Willsteed *et al*., 2018).

6.6.3 Possible mitigation measures

6.6.3.1 Plants, algae and invertebrates

No information is available on mitigation measures to avoid or reduce significant effects on plants, algae and invertebrates. The mitigation measures for habitats detailed in Chapter 6.2 could also serve to protect these groups.

6.6.3.2 Bats

Due to the limited empirical data on bats' presence and behaviour at sea (see Box 6-14), experience with mitigation measures for bats in the offshore wind energy sector is much more limited than it is on land. It is possible that micro siting and infrastructure design are effective measures for migratory bats at sea, but there is currently no evidence to support this. It is likely that adopting higher cut-in speeds[145] – and minimising blade rotation below the cut-in speed – would be an effective measure for migratory bats at sea (as for onshore). This is assumed because the most important predictor for the occurrence of Nathusius' pipistrelle in autumn

[144] 'Migrating bats at the southern North Sea - Approach to an estimation of migration populations of bats at the southern North Sea', Limpens, H.J.G.A., S. Lagerveld, I. Ahlén, et al. (2016/2017) Technical Report *Zoogdiervereniging* (Dutch Mammal Society) in collaboration with Wageningen Marine Research.
[145] Wind speed for starting wind turbine

at sea and at the coast appears to be low-to-moderate wind speeds. Research has been undertaken to determine the most appropriate environmental parameters that might be used to develop curtailment algorithms (Lagerveld *et al*., 2017). Case study 3-2 provides an example of curtailment instructions for offshore wind farms in the Netherlands to reduce collision risk for bats.

6.7 Decommissioning and repowering

6.7.1 Decommissioning

Decommissioning is the process whereby all or part of the wind energy infrastructure is removed, and the habitat restored to the condition stipulated by the competent national authority. Decommissioning may also be applied to individual turbines or groups of turbines as a measure to reduce ongoing effects as part of an adaptive-management plan (see Chapter 7) or as a result of a review by a competent authority.

Decommissioning might have negative effects in terms of the reef effect (see 6.5.2.1). Therefore, upon decommissioning there needs to be a balanced consideration of the advantages and disadvantages of leaving in place certain infrastructure, such as wind-turbine foundation bases and rock armour, which may confer benefits to marine mammals. On the other hand, decommissioned wind turbines or farms will only have positive effects for seabirds or migratory birds.

Few offshore wind energy developments have been decommissioned to date.

6.7.2 Repowering

Repowering is another opportunity to reduce collision risk, displacement effects and barrier effects. Repowering involves the removal of existing turbines and the building of new turbines, often of larger size and capacity. As a result, repowering projects usually use fewer turbines than the original wind energy development, and may use the existing or new foundations. Both micro siting and the influence of infrastructure design can be investigated to ensure deployment that has a low ecological risk.

To date, no offshore wind energy developments have yet been repowered. There is therefore no evidence about the use and effectiveness of measures applied in repowering to reduce likely significant effects.

7. MONITORING AND ADAPTIVE MANAGEMENT

7.1 Monitoring

7.1.1 Introduction

Monitoring is essential to ensure that: (i) the scientific basis underpinning the conclusions of an appropriate assessment remain valid in the long term; and (ii) any measures to avoid and/or reduce significant effects remain effective. Before a project can be allowed to proceed, an appropriate assessment must conclude beyond reasonable scientific doubt that an adverse effect on site integrity can be ruled out. However, it must be acknowledged that scientific knowledge and the facts at any given time have a limited 'shelf life'. There remains uncertainty about: (i) cumulative effects (see Chapter 3.4); (ii) the effects of climate change on biodiversity and ecosystem function; and (iii) other potential changes in the environment. Given this uncertainty, monitoring is an essential tool in ensuring that any significant effects can be identified in a timely manner and managed accordingly. Unexpected effects may arise for several reasons. For example, they may be identified after an assessment has concluded that there is no significant effect, because new scientific evidence has emerged. Or the conservation status and/or environmental conditions may have changed such that an effect that was previously not considered to be significant becomes so.

Monitoring requirements and standards exist in some Member States. These requirements and standards are mandatory as part of an EIA and considered examples of good practice for other countries to follow (Brownlie & Treweek, 2018; IFC, 2012).

Box 7-1 The EIA Directive (2014/52/EU)

"Member States should ensure that mitigation and compensation measures are implemented, and that appropriate procedures are determined regarding the monitoring of significant adverse effects on the environment resulting from the construction and operation of a project, inter alia, to identify unforeseen significant adverse effects, in order to be able to undertake appropriate remedial action. Such monitoring should not duplicate or add to monitoring required pursuant to Union legislation other than this Directive and to national legislation." (Paragraph 35)

The need for monitoring and adaptive management in the context of biodiversity and infrastructure development is outlined by many international organisations. Only on the basis of scientifically sound monitoring data can the design and implementation of plans or projects, including measures to avoid or reduce significant effects, be adapted over time to ensure their long-term validity, so called 'adaptive management'.

Box 7-2 Examples outlining the need for monitoring and adaptive management

Given the complexity in predicting project impacts on biodiversity and ecosystem services over the long term, the client should adopt adaptive management in which the implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project's lifecycle.

See: IFC 'Guidance Note 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources'.

A function of monitoring, in the context of management planning, is to measure the effectiveness of management. It is essential to know, and to be able to demonstrate to others, that the objectives are being achieved. Thus, monitoring must be recognised as an integral component of management and planning. It should be designed to identify and manage change in ecological character of the site.

See: Ramsar 'Handbook 18: Managing wetlands'.

The collection of monitoring data on both identified negative effects and the effectiveness of mitigation measures serves broader societal needs. Monitoring and gathering of data can provide the necessary knowledge to resolve the uncertainties encountered in deploying wind energy developments that are low in ecological risk.

There is often no standardised approach for monitoring. This makes it difficult to compare findings. Moreover, the findings from monitoring are rarely stored in an openly accessible, central repository for data. There is therefore great potential to improve the use of monitoring data from operational wind farms to underpin both impact assessments and permitting processes for new wind farms.

The case studies below provide some examples of strategic monitoring to overcome the challenges faced in making the best use of monitoring data.

7.1.2 Monitoring and wind energy developments

Monitoring programmes should include a similar set of indicators to those used for collecting baseline data before the drawing up of a wind energy development plan or project. The design of the monitoring programme should be considered during the planning of baseline-data collection so that the two processes can be harmonised at an early stage in the plan or project.

A well designed before-after-control-impact (BACI) model (GP Wind, 2012) remains one of the best models for environmental monitoring programmes (Smokorowski & Randall, 2017). The BACI model requires that baseline data (before the development begins) is collected using a standardised methodology in the area likely to be affected by the plan or project and at one or more control sites that are not affected by the plan or project. Ideally using the same methodology, data must then be collected at the plan or project area when the effect is measurable (after) and at the control site(s). Synchronising data collection between plan or project areas and control sites will improve comparability.

Like baseline-data collection, monitoring must be designed using a standardised approach to data collection and statistical analysis that is appropriate to the habitats or species in question. And to achieve the wider societal goals of monitoring it is also important that monitoring programmes are coordinated over space and time. This can be achieved by ensuring that monitoring programmes are drawn up at a strategic level when assessing the spatial plans for future wind energy development projects (see Case Study 7-1). Box 7-3 contains a summary checklist of key points to consider in monitoring.

It must be noted that the monitoring methods around offshore wind farms are mainly based on experiences and knowledge in the North Sea and the Baltic Sea. This means that the direct application of these methods to future projects in the Mediterranean Sea and the Black Sea should be done cautiously, or with some adjustment (given the different species and bio-communities in general). Examples of monitoring at offshore wind energy developments are shown in Case Study 7-4 en Case Study 7-5.

Box 7-3 Monitoring checklist

- Does the monitoring programme address all the significant effects (positive and negative) identified in the plan or project's appropriate assessment and/or EIA?
- Are the metrics that are monitored capable of providing biologically meaningful and relevant information in a cost-effective manner?
- Does the monitoring programme include metrics for measuring the implementation and effectiveness of mitigation measures? Is the frequency of monitoring appropriate for measuring implementation and effectiveness?
- Has the monitoring programme been designed to achieve sufficient statistical rigour to support adaptive management of the project's mitigation measures?
- Is there an opportunity to collect data consistently across a range of sites to assess effectiveness in the light of climate change?
- Is sufficient budget allocated for the monitoring programme? Who will provide the budget? For which period?

Source: adapted from CSBI, 2015

Case Study 7-1 Pre- and post-construction studies on the effects on birds at Storrun wind farm in the mountain region of northern Sweden

A good example of monitoring is the case of the Storrun wind farm, which comprises 15 2.5 MW turbines in Oldfjällen. Storrun was the first large wind farm built in a mountainous area in northern Sweden, near lake Övre Oldsjön and close to two Natura 2000 sites.

The authorities granted the construction permit on the condition that extensive field surveys and baseline studies be conducted to investigate the effects of the wind farm on birds. Intensive pre- and post-construction monitoring studies were conducted using a control area, making it possible to compare the situation before and after development. The results indicate that the wind farm at Storrun in general has a low impact on local bird life. Nevertheless, the results also confirmed earlier assumptions that grouse species such as the willow ptarmigan tend to collide with the tower structure.

Funding of these monitoring studies was planned through a governmental research programme, the purpose of which was to collect and provide scientific knowledge on the impacts of wind power on humans and nature. The results bolster the case for mitigation measures if wind-farm developments in mountainous areas are to continue.

Source: Naturvärdsverket rapport 6546 – Book of abstracts (2013) Pre- and post-construction studies on the effects on birds at Storrun wind farm in the mountain region of Jämtland, Sweden

Monitoring schemes covering multiple wind farms provide even better information. The advantages of monitoring schemes are that they create an extensive database providing sufficient information for assessing the effectiveness of mitigating actions. An extensive database can also provide more granular detail on issues such as average mortality for collision with birds and bats. Two examples of monitoring schemes covering multiple wind farms are provided below. Case Study 7-2 describes the national guidance for implementing monitoring of the impact of wind energy development projects on birds and bats in France. Case Study 7-3 describes a LIFE-funded project by the Renewable Grid Initiative (RGI) on better use and transparency of bird data collected by transmission system operators (TSOs).

Case Study 7-2 Monitoring protocol in France

The Ministry for Ecological Transition in France has developed national guidance for implementing monitoring of wind energy development projects in relation to birds and bats. The main objectives are to:

- assess the real effects (in terms of collision victims) and the effectiveness of mitigation measures;
- obtain sufficient data from several wind farms to calculate average mortality rates for birds and bats;
- collect a large amount of data at national level to underpin future policy and actions.

This protocol requires at least one post-construction monitoring measurement during the first 3 years of operation. If no significant effects are identified, at least one follow-up measurement should take place in the next 10 years. If significant effects are observed, corrective measures must be implemented and a new post-construction monitoring measurement must be carried out within the next year.

The protocol gives precise instructions on the periods of the year when monitoring must be conducted. These periods should always be relevant for the specific case. For example, some wind farms might have more effects on wintering waterfowl, while other wind farms might have more effects on breeding raptors. The protocol also gives precise instructions on: (i) the number of countings (at least 20); (ii) the number of turbines that must be monitored; (iii) the method for searching for carcasses, etc. For bats, the monitoring campaign must measure in pre-defined periods (specified in the protocol) both bat activity at the level of the turbine and carcasses on the ground.

Source: Protocole de suivi environnemental des parcs éoliens terrestres – revision 2018; https://eolien-biodiversite.com/IMG/pdf/protocole_de_suivi_revision_2018.pdf

Case Study 7-3 Better use and transparency of bird data collected by TSOs

Collisions and electrocutions of birds with power lines are a threat to some species across the globe. To minimise bird mortality on planned or existing infrastructure, TSOs collect lots of data on birds. However, although these data are used to guide decision making, they are seldom used outside the context of a specific project. RGI saw the potential to improve collective knowledge by finding ways to more effectively share study data on ‘bird-grid interactions’. With a systematic collation of studies, meta-analyses could be done to: (i) better understand the drivers of bird collision/electrocution risk;

(ii) better understand the effectiveness of mitigation measures; and (iii) ultimately provide science-based tools to guide route planning and mitigation measures.

In 2018, RGI teamed up with the British Trust for Ornithology (BTO) and the Royal Society for the Protection of Birds to understand: (i) what data TSOs are collecting; (ii) what TSOs and NGOs see as the opportunities of improved data sharing; and (iii) how best to practically achieve this data sharing. They produced a report on their findings. Some of the conclusions and recommendations are outlined in the three points below.

Key data requirements include:

- access to bird occurrence/abundance data for SEA and EIA;
- sensitivity mapping to prioritise risk (e.g. Belgium, Portugal, Slovakia);
- information on mortality, either as raw data for NGOs to be sure of effects or as peer-reviewed studies/reviews for TSOs to identify the most vulnerable species;
- information on mitigation effectiveness so TSOs can know what best to do.

There are significant institutional barriers to TSOs effectively sharing data, as well as limited time available. Both these issues need to be addressed.

A step-by-step approach could be adopted to foster greater data sharing and collaboration over time. This would require:

- the development of guidance on the field methods and data to be collected for EIAs, impact studies, and studies of mitigation effectiveness;
- making relevant studies more accessible and visible by sharing: (i) metadata; (ii) bibliographies of studies of powerline effects; (iii) and bibliographies of studies of mitigation effectiveness;
- a scoping study of the structure of data and information already being collected and shared – this would be a first step to developing a cost- and time-effective way of sharing data and information on a wider scale.

Source: https://renewables-grid.eu/topics/nature-conservation/bird-data-report.html

Case Study 7-4 East Coast Marine Mammal Acoustic Study (ECOMMAS)

The ECOMMAS project uses acoustic recorders, known as C-PODs, at 30 locations off the east coast of Scotland to detect echo-location clicks. These clicks are primarily made by harbour porpoises and bottlenose dolphins but they also come from other dolphin and cetacean species. At 10 of these locations, a broadband acoustic recorder has also been deployed to record ambient noise levels and other animal vocalisations.

Since 2013, these devices have been deployed every year throughout the summer (they have a battery life of around 4 months). Since 2015, two deployments have been undertaken per year, so there are data covering the period from April to November.

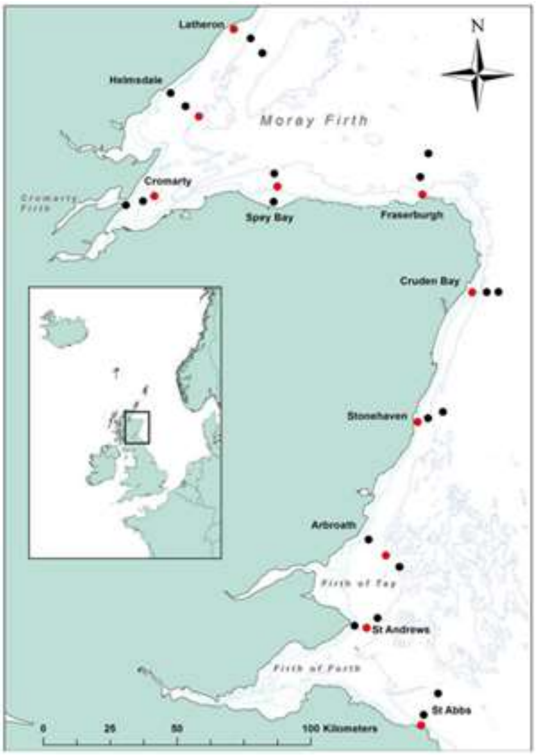

Figure 7-1: ECOMMAS study area

ECOMMAS monitoring locations

The ECOMMAS dataset is publicly available to download and currently covers the years from 2013 to 2016.

The programme provides valuable information for management of the Moray Firth Natura 2000 site, which was designated for the conservation of the bottlenose dolphin. The programme also provides valuable information on the harbour porpoise and other cetaceans listed under Annex IV of the Habitats Directive. Furthermore, the availability of a long-term data set is highly valuable for monitoring the construction of offshore wind farms in the region. The Beatrice offshore wind farm project has now installed piled (jacket) foundations, and other wind farms are planned in the region. In all cases, it is possible to relate the site-specific responses of cetaceans to construction/operation with wider regional variation in cetacean activity.

Source: Brookes, K. 2017. The ECOMMAS data. doi: 10.7489/1969-1
Data and further information available via: http://marine.gov.scot/information/east-coast-marine-mammal-acoustic-study-ecommas

Case Study 7-5 Dealing with uncertainty in the assessments of cumulative effects, Belgium

Since the beginning of 2016, 9 projects have been granted permits to build and operate wind and/or energy farms in the Belgian part of the North Sea. Of these, 3 were fully operational by the end of 2018. The 6 wind projects that are already licensed are in various stages of pre-construction. The consequences of the installation of wind turbines on Belgium's marine ecosystem must be monitored. As provided for in the environmental permit, the Belgian Federal Ministry coordinates a monitoring programme to estimate the positive and negative effects of the windmills at sea. This is financed by the wind farm operators who pay an annual fee. This approach has three main advantages, set out in the bullet points below.

- All monitoring efforts are coordinated, which results in a substantial increase in efficiency, both in improving results and reducing budget outlays.
- The private developers can focus on their core activities. Monitoring is done by experts.
- A monitoring programme steered by the government makes it possible to better identify monitoring needs.

Monitoring results are presented annually and in a coordinated way for the full area of the Belgian North Sea.

Source: https://odnature.naturalsciences.be/mumm/en/windfarms/

7.2 Adaptive management

Adaptive management ensures that the conclusions of the appropriate assessment are maintained throughout the project's life cycle.

The principles of adaptive management are as follows:

- observe: undertake systematic collection of data (monitoring);
- assess: i) analyse monitoring data; and (ii) identify any changes that could alter the previous prediction of 'no adverse effect on site integrity beyond reasonable scientific doubt'
- inform: report the analysis to key stakeholders;
- act: if necessary, initiate management actions to reduce unforeseen significant effects;
- repeat the cycle to ensure that the measures implemented are effective.

An adaptive-management programme must ensure that there is:

- appropriate financial provision to cover the estimated costs of monitoring, potential consultation, and management actions (excluding the cost of mitigation measures);
- approval of the competent national authority before engaging in any adaptive management;
- participation from all key stakeholders in the implementation of monitoring and adaptive management;
- open and transparent access to the monitoring data and details of the management actions taken for all key stakeholders.

In exceptional cases, adaptive management can have consequences for the economic viability of a wind farm. For instance, this is the case when the authorities insist on permanently stopping the operation of one or more turbines. Of course, it is in the interest of all involved stakeholders to avoid such situations by conducting detailed baseline assessments before the deployment of wind farm infrastructure.

A useful source of further information on adaptive management is available via the outputs of the 'WREN' adaptive-management white paper (Hanna *et al*., 2016).

The white paper also contains a number of case studies. Some of them are highlighted in Case Study 7-6.

Case Study 7-6 Examples of adaptive-management approaches in EU Member States

- Candeeiros wind farm is located in the central part of **Portugal** and has implemented an iterative approach to post-construction bird-mortality monitoring. After 3 years of post-construction bird monitoring, the common kestrel (*Falco tinnunculus*) emerged as the species most commonly killed at the wind farm. As a result, the monitoring programme was changed to study the kestrel population and evaluate the significance of the wind farm's effects on this species. The effect of the wind farm on the local kestrel population was considered significant, and this led to the development of a site-specific mitigation programme (onsite minimisation and offset/compensation). The mitigation programme included: (i) planting native shrubs; (ii) enhancing habitat and scrub areas away from turbines; (iii) and promoting extensive livestock grazing away from the turbines to enhance habitat heterogeneity. The implementation of the mitigation programme started in 2013 and continued until 2016. Monitoring of the kestrel population and carcass surveys have continued in order to evaluate the success of the mitigation measures.
- Adaptive management is not required in **Germany**, and no formal regulations outline how it should be used for wind energy projects in the country. Nevertheless, the principles of adaptive management have been applied to several different projects. For example, the Ellern wind farm in Germany's southwest Rhineland-Palatinate attempted to mitigate the collision mortality of bats by curtailing turbine operation at wind speeds below 6 m/s from April to October. The mitigation was required locally, specified in the wind-farm permit, and based on Federal guidelines. Data were collected during the first year of operation through carcass surveys and nacelle[146] monitoring. After a year of operation, the monitoring data were compared with thresholds set by a group of stakeholders, including nature conservation

[146] A nacelle is a cover housing that houses all of the generating components in a wind turbine

organisations and the project sponsor. As a result, the curtailment methods were altered to ensure that the thresholds were met. Monitoring was only required for the first 2 years of wind-farm operation, and there are no plans for subsequent changes to the monitoring plan.

- In a land-based example, a 50 MW wind energy project in the **UK** was developed in moorland habitat over 10 years ago. Collision-risk models were developed before construction began that suggested the wind farm could pose a risk for hen harriers (*Circus cyaneus*). Monitoring was carried out to determine how to most effectively manage heather moorland habitat to benefit the hen harrier through rotational burning, drain-blocking, etc. The monitoring results inform annual decisions about how to best manage the moorland habitat, which in return reduces the collision risk for hen harriers. Understanding of the extent to which these activities benefit the species has improved over time.
- At wind farms located in La Janda (in Cádiz, in the south of **Spain**), large numbers of birds were dying due to blade collision. After several meetings, researchers proposed a novel method for reducing bird mortality: it consists of monitoring bird flight in the field, especially the flight of the more affected species such as the Griffon vulture (*Gyps fulvus*). When the wind farm operators detect a dangerous situation, they can stop the relevant turbines and restart them after the birds have left the area. Training was provided to operators to ensure accurate detection of collisions, and the area was surveyed for bird carcasses. Daily monitoring for collisions was carried out from early morning to late in the evening. The agreement reached by all parties was as follows: wind energy companies paid for the system; researchers carried out the data analysis and interpretation; and environmental agencies awaited the results before taking more punitive measures. After 2 years, results showed a 50% decrease in mortality and a reduction in energy production of approximately 0.7% per year (de Lucas *et al*., 2012). Since then, this monitoring method has continued and bird-mortality rates continue to decrease.

Source: 'WREN' adaptive-management white paper (Hanna *et al*., 2016)

Case Study 7-7 Dutch offshore-wind ecological programme (Wozep)

In 2015, the Ministry of Economic Affairs (EZ ED 2020) in the Netherlands set up an integrated monitoring and research programme (Wozep) to study gaps in knowledge about the effects of offshore wind farms on the ecosystem of the southern North Sea. This general programme was drawn up in response to a recommendation from the Directorate-General for Public Works and Water Management of the Netherlands (RWS) on the basis that knowledge gaps were primarily general rather than specific for individual offshore wind farms.

The current monitoring programme (Rijkswaterstaat, 2016) describes the scope of monitoring planned for the period 2017-2021. Importantly, the programme outlines the work planned, allowing room for flexibility. This flexibility may be required if there are:

- changes following results from the undertaken research;
- changes in policy; and
- future changes in priorities.

Specifically, monitoring and research in Wozep must contribute to the following objectives:

- They must reduce scientific uncertainties from knowledge gaps and assumptions from the framework for the assessment of ecological and cumulative effects, the EIA, and the appropriate assessment.
- They must reduce uncertainties from knowledge gaps and assumptions about long-term effects and upscaling of offshore wind farms (in relation to plans by offshore wind farms that may follow in line with national ambitions to expand renewable energy such as wind and solar).
- They must determine the effectiveness of mitigation measures (in the context of the 40% cost reduction in the Dutch Energy Agreement, concluded by the government with employers, trade unions, environmental organisations and others).

The above objectives are from the Dutch government's commitment to apply adaptive-management principles in the permitting process for new offshore wind farms (IEA Wind Task 34 (WREN)). Programmes are in place for birds, bats, marine mammals, fish and benthos.

This approach is a national-level programme of adaptive management. It is linked to international collaboration between several countries to develop similar approaches for wind energy.

Source:
Rijkswaterstaat (2016) Offshore wind energy ecological programme (Wozep)
Monitoring and research programme 2017-2021.
IEA Wind Task 34 (WREN) Technical Report, December 2016 Adaptive management white

paper, full text available on: www.tethys.pnnl.gov/about-wren
https://www.noordzeeloket.nl/publish/pages/122275/offshore_wind_ecological_programme_wozep_-_monitoring_and_research_programme_2017-2021_5284.pdf
Further information available via: www.noordzeeloket.nl

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9. APPENDICES

APPENDIX A – CASE STUDIES

Case study	Member State	Onshore/offshore		Good practice for																				
		Onshore	Offshore	Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
Case study 3-1 Guidance on assessing the spatial scope of cumulative impact assessment related to bird populations in Flanders (Belgium)	BE	X											X						X			
Case study 3-2 Dealing with cumulative impact assessment for offshore wind in The Netherlands	NL		X										X		X				X		X	
Case study 3-3 Applying the precautionary principle in wind energy spatial planning - Capercaillie in the Black Forest (Germany) (LIFE project: LIFE98_NAT_D_005087)	DE	X		X	X					X					X				X			
Case study 3-4 The ‘Rochdale Envelope’: covering uncertainty in project design trends – Application to the Orsted offshore wind farm ‘Hornsea 3’	UK	X								X					X							
Case study 3-5 Multi-stakeholder cooperation in Germany	DE	X	X	X				X			X	X		X	X	X	X	X	X	X	X	
Case study 3-6 Multi-stakeholder cooperation in France	FR	X					X			X	X		X	X	X	X	X	X	X	X		

Case study	Member State	Onshore/offshore		Good practice for																		
		Onshore	Offshore	Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
Case study 4-1 Wind farm sensitivity map for birds and bats in Flanders (Belgium)	BE	X		X	X							X		X	X				X	X		
Case study 4-2 Soaring bird sensitivity map for wind energy development in Thrace (Greece)	EL	X		X	X							X		X	X	X			X			
Case study 4-3 SeaMaST (Seabird Mapping and Sensitivity Tool): a tool for assessing wind farm effects in English territorial waters	UK		X	X	X							X							X			
Case study 4-4: The Edulis project, an example of combined wind energy generation and aquaculture in the North Sea (Belgium)	BE		X	X										X								
Case study 4-5: Flat oyster restoration on offshore wind farms (Netherlands)	NL		X	X										X								X
Case Study 5-1 Effects on steppic grasslands by construction of wind turbines in Dobrogea (South-eastern Romania)	RO	X										X			X							X
Case Study 5-2: RENEBAT II and RENEBAT III / ProBat	DE	X	X											X						X		
Case Study 5-3: Use of ultrasonic acoustic devices (UADs) as a bat deterrent technique	International	X	X											X				X		X		

Case study	Member State	Onshore/offshore		Good practice for																		
		Onshore	Offshore	Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
Case Study 5-4 Combining radar and direct observation to estimate the collision risk for pelicans at a proposed wind farm on the Cape West Coast, South Africa	International	X										X		X	X	X			X			
Case Study 5-5: Significance assessment approach in relation to birds and wind energy in Flanders (Belgium)	BE	X									X								X			
Case Study 5-6: GenEst, A tool for evaluating collision mortality at wind energy developments	International	X										X							X	X		
Case Study 5-7: Identification of displacement effects on the Golden Eagle *(Aquila* chrysaetos) through GPS tracking in France	FR	X		X								X			X	X	X	X	X			
Case Study 5-8: Observer-assisted shutdown on demand (Tarifa, Spain)	ES	X												X				X	X			
Case Study 5-9: Radar-assisted shutdown on demand, Barão de São João Wind Farm, Portugal	PT	X												X				X	X			
Case Study 5-10: Shutdown during crop harvesting, Germany	DE	X												X					X			
Case Study 5-11: Increased visibility of painted of	NO	X												X					X			

Case study	Member State	Onshore/offshore: Onshore	Onshore/offshore: Offshore	Good practice for: Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
turbine blades and towers at Smøla wind farm, Norway																						
Case Study 5-12: Use of an automatic collision avoidance system to reduce the collision impact on *pelicans (*Pelecanus crispus *and* Pelecanus onocrotalus) at Prespa Park, Greece	EL	X												X					X			
Case Study 5-13: Habitat management to reduce collision risk for Lesser kestrel *(Falco* naumanni), Spain	ES	X										X		X				X	X			X
Case study 5-14: Reducing the collision risk of the white-tailed eagle (Haliaeetus albicilla) by repowering the Smøla Wind farm, Norway	NO	X	X			X						X		X					X			
Case study 5-15: Reducing the collision risk of species of tern by repowering the Zeebrugge Wind farm, Belgium	BE	X	X			X						X		X				X	X	X		
Case study 6-1 Restoration of degraded habitat for the construction of the Anholt offshore wind farm in Denmark	DK		X											X								X

Case study	Member State	Onshore/offshore		Good practice for																		
		Onshore	Offshore	Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
Case Study 6-2 Estimating the flight height of seabirds using LiDAR	International		X													X	X	X	X			
Case Study 6-3 Marine-mammal population models	UK		X												X						X	
Case Study 6-4 Assessing the impact of noise from pile driving on marine mammals, Germany	DE		X								X	X									X	
Case Study 6-5 Permit conditions related to harbour porpoises for an offshore wind farm in Sweden	SE		X		X						X	X		X							X	
Case Study 6-6 Mitigation of noise effects from pile driving on marine mammals, Germany	DE		X									X		X							X	
Case Study 7-1 Pre- and post-construction studies on the effects on birds at Storrun wind farm in the mountain region of northern Sweden	SE	X		X								X			X	X		X	X			
Case Study 7-2 Monitoring protocol in France	FR	X							X			X		X				X	X	X		
Case Study 7-3 Better use and transparency of bird data collected by TSOs		X			X										X			X	X			
Case Study 7-4 East Coast Marine Mammal Acoustic Study (ECOMMAS)	UK		X	X	X							X									X	
Case Study 7-5 Dealing with uncertainty in the	BE		X										X	X	X		X	X	X	X	X	X

Case study	Member State	Onshore/offshore		Good practice for																		
		Onshore	Offshore	Spatial planning	Sensitivity mapping	Repowering	Decommissioning	Stakeholder cooperation	Risk-based approach	Precautionary approach	Significance	Impact assessment	Cumulative assessment	Mitigation measures	Data	Baseline monitoring	Monitoring during construction	Post-construction monitoring	Birds	Bats	Marine mammals	Habitats
assessments of cumulative effects, Belgium																						
Case Study 7-6 Examples of adaptive-management approaches in EU Member States	EU MS	X							X									X	X	X		
Case Study 7-7 Dutch offshore-wind ecological programme (Wozep)	NL		X												X		X	X	X	X	X	X

APPENDIX B – INTERNATIONAL INITIATIVES

This chapter outlines the most relevant conventions for renewable energies (such as wind energy) and biodiversity conservation in Europe. Several conventions have also adopted specific recommendations and resolutions on wind farms and biodiversity.

International nature and biodiversity conventions and agreements

The EU and its Member States, as well as most other European countries, are contracting parties to various international environmental conventions and agreements. European and national legal frameworks on nature and biodiversity conservation must therefore also take full account of the commitments entered into under these conventions and agreements.

These conventions and agreements have helped to shape the legal framework for biodiversity policy and legislation within the EU. They have also helped shape the relationship between the EU and other countries. Several conventions and agreements have also adopted specific recommendations and resolutions on energy infrastructure and wildlife, notably on overhead power lines.

Convention on Biological Diversity (CBD)[147]

The CBD is a global treaty adopted in Rio de Janeiro in June 1992. It widened the scope of biodiversity conservation from species and habitats to the sustainable use of biological resources for the benefit for mankind. To date, 193 countries are parties to the convention.

Convention on the Conservation of European Wildlife and Natural Habitats (BERN CONVENTION)[148]

The Convention on the Conservation of European Wildlife and Natural Habitats, also known as the Bern Convention, came into force in 1982. It has played a significant role in strengthening work on biodiversity conservation in Europe. It has been ratified by the EU, four countries in Africa, and 45 Member States of the Council of Europe. An important objective of the convention is the creation of the Emerald Network[149] of areas of special conservation interest. This network operates alongside the EU Natura 2000 Network. In 2004, the Bern Convention Standing Committee adopted a recommendation (No 110) on minimising the adverse effects of above-ground electricity-transmission facilities (power lines) on birds[150]. In 2011, the Standing Committee asked the parties to the convention to report twice a year on their progress in implementing recommendation No 110.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)[151]

The CMS, or Bonn Convention, aims to preserve migratory species throughout their natural geographical range. It entered into force in 1983 and has now been signed by 116 parties. Several resolutions, recommendations and agreements signed under this convention are relevant to the management of conflicts between migrating animals and energy infrastructure, in particular overhead power lines. These are outlined briefly below.

Resolution 7.4[152] of the CMS on the electrocution of migratory birds calls on all parties and non-parties to curb electrocution risk by taking appropriate measures in planning and constructing lines.

Catalogue of measures contained in document UNEP/CMS/Inf.7.21.

The action plan of the Memorandum of Understanding on the Conservation of Migratory Birds of Prey in Africa and Eurasia (Raptors MoU)[153] considers power lines as the principle threat to birds and formulates a priority action to reduce their effect. The plan aims at 'promoting, as far as possible, high environmental standards, including

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[147] https://www.cbd.int/
[148] www.coe.int/t/dg4/cultureheritage/nature/bern/default_en.asp
[149] www.coe.int/t/dg4/cultureheritage/nature/EcoNetworks/Default_en.asp
[150] https://wcd.coe.int/wcd/ViewDoc.jsp?Ref=Rec(2004)110&Language=lanEnglish&Ver=original&Site=DG4-Nature&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FDC864
[151] www.cms.int
[152] For example, available from www.cms.int/bodies/ScC/12th_scientific_council/pdf/English/Inf08_Resolutions_and_Recommendations_E.pdf
[153] www.cms.int/species/raptors/index.htm

through EIAs, in the planning and construction of structures to minimise their impact on species, particularly by collision and electrocution, and seeking to minimise the impact of existing structures where it becomes evident that they constitute a negative impact for the species concerned'.

The action plan proposes the following four activities on power lines and raptors.

- Review relevant legislation and take steps where possible to make sure that legislation requires all new power lines to be designed to avoid electrocuting birds of prey.
- Conduct risk analysis at important sites to identify and address actual or potential causes of significant incidental mortality from human causes (including fire, laying of poison, pesticide use, power lines, and wind turbines).
- Where feasible, take necessary actions to ensure that existing power lines that pose the greatest risk to birds of prey are modified to avoid electrocuting birds of prey.
- Monitor the impacts on birds of prey of power lines and wind farms, including through analysis of existing data such as ringing data.

The Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA)[154] calls for coordinated action throughout migration routes or flyways of migratory waterbirds. It came into force in 1999. The agreement covers 119 countries and 235 species of waterbirds. The EU ratified AEWA in 2005.

The Agreement on the Conservation of Populations of European Bats (EUROBATS)[155] aims to protect all 45 species of bat found in Europe. It entered into force in 1994. Currently 32 countries have signed up. Implementation of common conservation strategies and international experience-sharing are its main activities. Resolution 8.4 explicitly deals with wind turbines and bat populations[156].

The Agreement on the Conservation of Small Cetaceans of the Baltic and North Sea (ASCOBANS)[157] was launched in 1991. It aims to coordinate measures to reduce the negative impact of by-catches, habitat loss, marine pollution, and acoustic disturbances among the 10 parties. A resolution on the adverse effects of sound on small cetaceans – relevant for the potential impact of energy infrastructure – was adopted in 2006.

The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic Area (ACCOBAMS)[158] is a cooperative framework for the conservation of marine biodiversity in the Mediterranean and Black Seas. Its main purpose is to reduce the threat to – and improve knowledge about – cetaceans in these seas. The agreement came into force in 2001.

Convention on Wetlands of International Importance (RAMSAR)[159]

The Convention on Wetlands of International Importance, also known as the Ramsar Convention, is an intergovernmental treaty providing a framework for national action and international cooperation for the conservation and wise use of wetlands. It was adopted in 1971 and amended in 1982 and 1987. There are now 160 parties to the Convention, and 2006 sites worldwide have by now been added to the Ramsar list of wetlands of international importance. The Convention does not provide for ratification by supranational bodies such as the EU, but all Member States of the EU are contracting parties.

Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)[160]

OSPAR guides international cooperation on a range of issues, including: (i) the conservation of marine biodiversity and ecosystems; (ii) the impact of eutrophication and hazardous substances; and (iii) monitoring and assessment. It was launched in 1992, following the merger of the previous Oslo and Paris Conventions (from 1972 and 1974). Several studies on the potential impact of energy infrastructure on the marine environment have been initiated under the auspices of this Convention.

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[154] www.unep-aewa.org
[155] www.eurobats.org
[156] https://www.eurobats.org/sites/default/files/documents/pdf/Standing_Committee/Doc.StC14-AC23.15-DraftResolution8.4_WindTurbines.pdf
[157] www.ascobans.org
[158] www.accobams.org
[159] www.rasmsar.org
[160] www.ospar.org

Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM)[161]

HELCOM, or the Helsinki Convention, covers the Baltic Sea basin plus all inland waters in its catchment area. It was adopted in 1980 and revised in 1992. The EU and all countries around the Baltic Sea are contracting parties.

Convention for Protection against Pollution in the Mediterranean Sea (BARCELONA CONVENTION)[162]

The Convention for Protection against Pollution in the Mediterranean Sea, also known as the Barcelona Convention, aims primarily to regulate and reduce the negative impact of all kinds of pollutants in the Mediterranean basin. It was set up in 1976 and last amended in 1995. Most countries bordering the sea have signed up to it.

[161] www.helcom.fi
[162] www.unep.ch/regionalseas/regions/med/t_barcel.htm

Table 9-1 Examples of good-practice approaches to overcoming typical uncertainty encountered in assessing wind energy development

Uncertainty	Good practice	
	Plan	**Project**
Importance of the location of wind energy developments to the integrity of the Natura 2000 network at the stage of selecting the development site	Undertake wildlife-sensitivity mapping at the regional/national scale to identify a gradient of constraint to wind energy development	Use the wildlife-sensitivity mapping at the regional/national scale to identify locations, and where appropriate undertake wildlife-sensitivity mapping at the project-spatial scale
Incomplete knowledge of baseline conditions Examples: • Extent and quality of marine benthic habitats • Distribution and abundance of marine mammals and birds at sea • Distribution, size and type of bat roosts	Undertake regional/national survey programmes to fill knowledge gaps in the plan study area	Undertake surveys to fill knowledge gaps in the project study area
Incomplete knowledge of species behaviour Examples: • Foraging routes of bats • Nocturnal foraging behaviour of terrestrial and marine birds • Flight height and speed of birds in flight	Undertake regional/national research programmes to fill knowledge gaps	Undertake surveys to fill knowledge gaps relevant to the project study area, and/or gain expert opinion from national and/or international specialists
Apportioning effects to a SAC/SPA, particularly when the species is dispersed in the wider population	Undertake regional/national research programmes to fill knowledge gaps	In the absence of an existing agreed approach with the competent national authority, set up an expert working group including the competent national authority to establish an agreed approach to apportioning effects to an individual SAC
Accuracy of predictive models Examples: • Collision-risk models for birds • Species' population models for marine mammals and birds	Present clearly and transparently the levels of uncertainty related to the predictions Assess significance using the predictions and the associated upper and lower confidence limits Set up an expert working group including the competent national authority to establish an agreed approach to determining significance based on predictive modelling Species' population models to be at the regional/national scale (requires regional/national baseline data)	Present clearly and transparently the levels of uncertainty related to the predictions Assess significance using the predictions and the associated upper and lower confidence limits Set up an expert working group including the competent national authority to establish an agreed approach to determining significance based on predictive modelling Species' population models to be at the scale of Natura 2000 site(s) within the project study area (requires Natura 2000 site baseline data)

APPENDIX D – WILDLIFE-SENSITIVITY MAPPING MANUAL

The wildlife-sensitivity mapping manual provides a comprehensive overview of the datasets, methodologies and GIS applications needed to develop effective wildlife-sensitivity-mapping approaches within the EU. The manual draws together the information needed to develop such approaches for a number of renewable energy technologies, including wind, solar and ocean energy. The manual focuses on a number of key wildlife attributes. These include all species and habitats protected by the EU Nature Directives, with particular emphasis on birds, bats and marine mammals. It includes key recommendations on the most suitable data types and sensitivity analysis. It also contains extensive links to external websites and documents which provide further in-depth information and examples.

The manual is an interactive tool. Users can navigate the content using the icons on the navigation bar or by following links from the various chapter and sub-chapter headers. In this respect, the manual is designed much like a website.

Some key elements of the manual are presented in the bullet points below and in further detail in the remainder of this annex:

- a step-by-step approach to wildlife-sensitivity mapping;
- the development of a sensitivity-scoring system;
- an overview of spatial biodiversity data;
- key recommendations.

This manual is one of the deliverables of the European Commission project "Reviewing and mitigating the impacts of renewable energy developments on habitats and species protected under the Birds and Habitats Directives"[163].

A step-by-step approach to wildlife-sensitivity mapping

Identify the renewable energy types to be included and the species and habitats likely to be affected

What renewable-energy infrastructure will be included (wind, solar, geothermal, ocean)? What species or habitats are likely to be affected? How are they likely to be affected?

Affected species/habitats

- Consider species / habitats likely to coincide with development (at any stage of lifecycle) – and consider all life history phases (breeding, migration, non-breeding etc.).
- Consider different phases of development (e.g. construction, operational phases) as well as associated infrastructure (e.g. implications of grid connections with transmission lines).
- Consider which species / habitats are sensitive to development (characteristics, population dynamics).
- Consider which species / habitats are of conservation concern (e.g. those listed within the Birds and Habitats Directives).

Likely impact

- Consider how species are impacted: habitat loss and degradation; collision with infrastructure; avoidance; displacement; and barrier effects.

Compile distributional datasets on sensitive species, habitats and other relevant factors

Review what distributional data are available and consider whether additional data should be collected

- In case the datasets are spatially incomplete, consider whether it will be necessary to use modelling, based on habitat and landscape predictors, to forecast distribution in under sampled localities (e.g. Density Surface Modelling).
- It is also important to openly highlight data deficiencies and other methodological shortcomings.

Develop a sensitivity-scoring system

Assign sensitivity scores to species and habitats based on identified characteristics (species behaviour, habitat fragility, conservation status, etc.).

Generate the map

163 https://ec.europa.eu/environment/nature/natura2000/management/natura_2000_and_renewable_energy_developments_en.htm

What is the most appropriate mapping format and GIS software? What is the most appropriate mapping unit?

- Generate a grid based on an appropriate mapping unit and overlay the species distributions (or models) and potentially other useful datasets, including relevant buffer zones.
- Identify the species present within each grid cell (i.e. where a species location (or part of a buffer) is included within a grid square).
- For each grid square calculate a score using the species-sensitivity scoring system.

Interpretation

How do the sensitivity scores relate to risk? How should the map be interpreted?

- Group sensitivity scores in categories indicative of their level of sensitivity (e.g. very high, high, medium, low). Where data gaps exist in may not be advisable to assign areas as having 'low' sensitivity. In such circumstances, it may be preferable to use the terms 'unknown' or 'uncertain' sensitivity. On occasion, categories are chosen that indicate a particular prescription (e.g. no-go areas vs. low risk areas).
- Develop guidance material to sit alongside the map that fully explains what data are used, how the map is generated, how it should be interpreted and what the caveats are for interpretation.

Developing a sensitivity-scoring system

Some wildlife-sensitivity maps simply present biological data visually and leave the interpretation of the data to the end-user. However, in most cases, merely knowing the geographic extent of a biological feature, e.g. the range of a vulnerable bird species or the location of a bat roost, is of limited value. What is also needed is interpretation that shows what the incidence of a particular biological feature means for the prospect of renewable energy development.

The simplest interpretation is to collectively assign all data layers as sensitive. The only explanatory embellishment might be to buffer features to represent dispersion (for instance, known dispersal from a roost site) or in recognition of uncertainty over the accuracy of the data. It may be that some features, for instance a vulture colony, receive a buffer of many kilometres, while others, such as some bat colonies, receive a smaller buffer.

Buffer zones should be determined:

- **with reference to an established protocol used in similar approaches elsewhere;**
- **with reference to known biological parameters as reported in the literature (for instance the documented range size of a particular breeding bird species);**
- **in a precautionary manner that recognises data and knowledge limitations.**

In some approaches, all sensitivity features and any associated buffers are described as 'no-go areas', in which zero development is recommended. However, the majority of wildlife sensitivity mapping approaches avoid such an absolute prognosis in recognition of the limitations of both spatial data and mapping techniques. Indeed, in some, albeit limited, circumstances it may be possible to sufficiently mitigate impacts even at highly sensitive locations such that development can proceed.

Most wildlife sensitivity maps approaches provide a gradient of sensitivity. At its simplest, this can entail classifying certain core features, such as protected areas, as no-go sites and less sensitive, secondary locations, as sites where development could prove problematic and where caution is advised. More complex mapping exercises assign sensitivity by weighting features in relation to known parameters that increase sensitivity. Factors that enhance sensitivity generally fall into the following categories: species characteristics, habitat characteristics, population dynamics and conservation status.

- **Species characteristics**

Species behaviour: some species are more sensitive to renewable energy development due to certain behavioural traits. Degree of exposure may be the most significant factor underpinning a species' sensitivity. For instance, those bird and bat species most likely to collide with wind turbines are likely to be those that spend the most time flying at a height corresponding to the rotor sweep zone, roughly between 30 – 150 m above the ground.

Species morphology: certain species may be more sensitive due to their morphology. For instance, bat species with wings designed for fast flight in open spaces are more susceptibility to collision with wind turbines. In birds, wing loading (the relationship between wing area and body weight) is also regarded as a key factor governing collision risk. Eye structure may be equally key, for instance, the visual field of Gyps Vultures contains a small binocular region and large blind areas above, below and behind the head, which may render them frequently sightless in the direction of travel.

Migratory behaviour: certain species may be more sensitive due to the nature of their migration. For instance, some species migrate along well-defined routes and thus occur in high concentrations. If renewable energy infrastructure is located along these routes, especially at key bottleneck sites, the likelihood of impact is increased.

- Habitat characteristics

Habitat fragility: certain habitats are more sensitive to renewable-energy developments.
Habitat dependence: certain species are dependent on a limited range of habitats and could be jeopardised if too great a proportion of that habitat is exposed to development.

- Population dynamics

Proportion of global/regional/national population. The larger the proportion of a population that would be affected, the greater the sensitivity.
Life-history traits. Direct mortality, such as that resulting through turbine collisions, are more likely to result in population level effects in species which display traits associated with slower rates of reproduction and higher reliance of adult survivorship.

- Conservation status

Global, EU, regional or national conservation status. Species of conservation concern, such as those listed as globally threatened on the IUCN Red List, national Red Lists or the EU Nature Directives are particularly important to identify.

Once a list of at-risk species and habitats has been created, these can be scored in terms of the level of their sensitivity. Such lists should be based on a thorough investigation of the scientific literature and through consultation with key experts. The scoring of parameters, such as flight height or collision avoidance rate, should be based on experimental evidence. However, this will not always be possible and it may be necessary to extrapolate from known parameters for closely related taxa. It should be noted that behaviours and responses can vary significantly even among taxonomically close species.

Theoretical example of applying a sensitivity scoring system

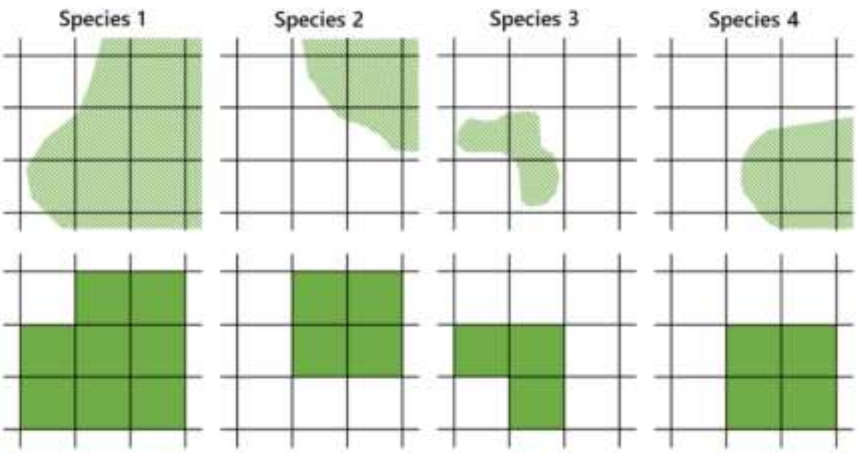
In this simple, theoretical example, four species are scored in relation to their sensitivity to a form of renewable energy. The spatial distribution of the four species is fitted to a grid system. Within each grid square the scores of those species present are summed to create an overall score for each grid cell and therefore a rudimentary sensitivity map.

STEP 1: The four species are scored in relation to the morphological, behavioural and population dynamic traits that enhance their sensitivity and their conservation status. These scores are then summed to produce an overall sensitivity score (see example scoring system). In this example, species regarded as highly or very highly sensitive in relation to one parameter are automatically placed in the 'HIGH' category irrespective of how they score for other parameters.

Morphology/behaviour/population-dynamics score (1 = low sensitivity, 2 = medium sensitivity, 3 = high sensitivity, 4 = very high sensitivity)
Conservation score (0 = low, 1 = medium, 2 = high, 3 = very high)
Conservation scores are doubled before adding to morphology/behaviour/population-dynamics score
Sensitivity score MEDIUM (3-8), HIGH (9 – 14), VERY HIGH (15 – 20)
Any species scoring 3 or 4 for morphology/behaviour/population-dynamics score is automatically in the HIGH category

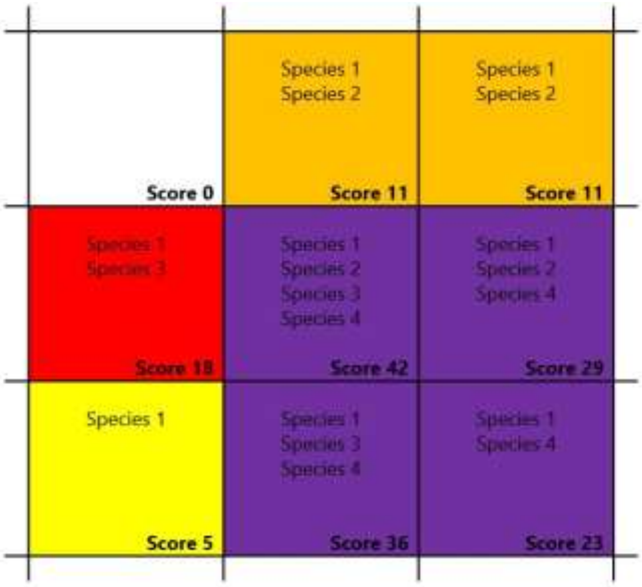
Species	Morphology	Behaviour	Population dynamics	Conservation status	Sensitivity score
Species 1	3	1	1	0	5
Species 2	2	2	2	0	6
Species 3	4	2	1	3	13
Species 4	4	4	4	3	18

STEP 2: Spatial data on the distributions of the four species are then fitted to an appropriate grid system.

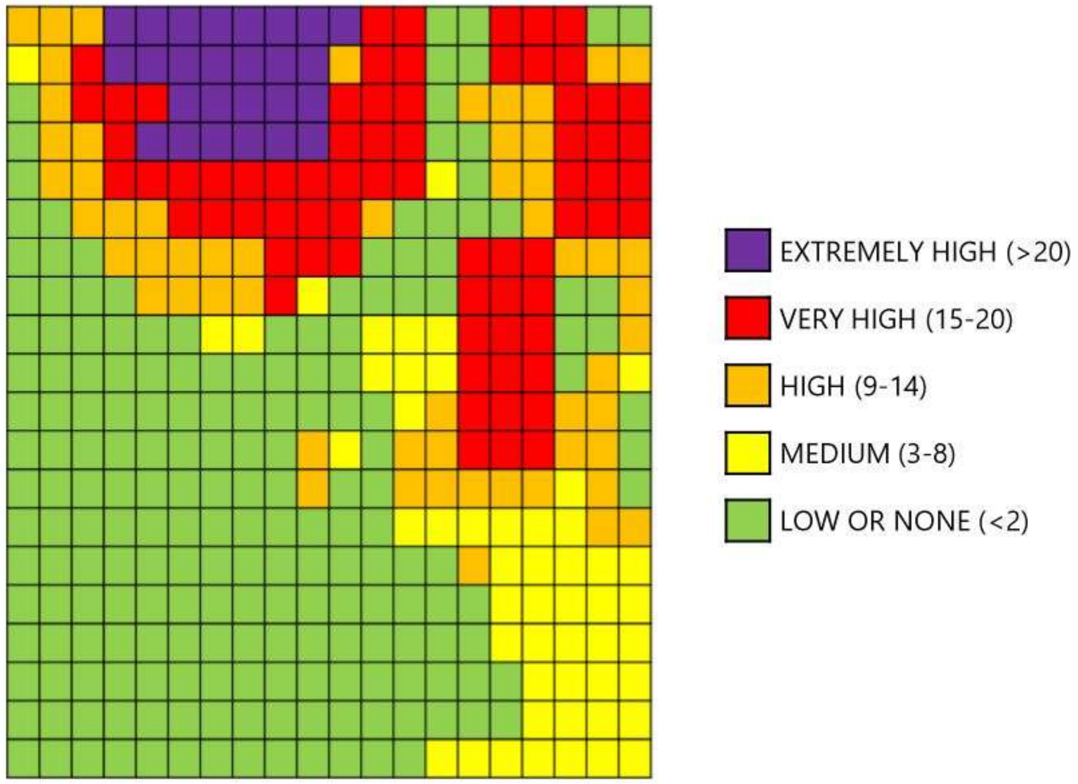


STEP 3: Combined sensitivity scores can then be applied by summing the sensitivity scores for each species present within a grid square, thus producing an overall score for each gird cell. The figure depicts a theoretical grid weighted in accordance with the previous sensitivity scores. This simple example is based on presence / absence; however, where population data is available, this can be used to weight each grid square in relation to the number of individuals per species or the proportion of the global or regional population of each species present.

Sensitivity Score: MEDIUM (3-8), HIGH (9-14), VERY HIGH (15-20), EXTREMELY HIGH (>20)



STEP 4: The final sensitivity map depicts combined sensitivity in relation to four theoretical species across a theoretical landscape. In such maps, sensitivity levels are typically depicted using different colours



Overview of spatial biodiversity data

Wildlife sensitivity maps should utilise the most accurate and up-to-date data on the distribution and abundance of potentially sensitive species and habitats. Ideally, such data will be collected systematically using a standardised protocol such as that used for the European Breeding Bird Atlas developed by the European Bird Census Council. However, often data is generated in an ad hoc manner, such as with observation records collated through citizen science projects or through field surveys limited in geographic scope. Biases in survey effort or focus should be acknowledged and the level of certainty clearly specified. Often species distributions will need to be inferred from generalised species range maps, habitat maps or tracking data. Again, any underlying assumptions and shortcomings associated with such models should be clearly specified.

It should be recognised that the current distribution of a species may be much more restricted that it was historically and indeed more restricted than that aimed for in conservation recovery targets. Therefore, it may be preferable to develop predicted range maps based on a desired distribution following population recovery and restoration.

Inevitably, the quality of data, and the level of knowledge on now best to interpret it, will vary considerably between different regions and taxonomic groups. For example, far less data exists on the distribution of bat species within Europe than bird species. Even where data is limited and the resultant sensitivity maps are crude and preliminary, they still serve as a useful early stage planning tool. It is important, however, to clearly acknowledged the limitations.

There are numerous datasets on the distribution and abundance of European wildlife. There are also several abiotic and biotic environmental spatial datasets that can be useful as explanatory variables to model distributions.

A broad range of datasets are available through the European Environmental Agency (EEA) website. Through this portal data and information is available through reports submitted on the Birds and Habitats Directives. EU Menber States are obliged to report every six years on the status of birds and habitats through Articles 12 and 17 reports respectively. Publicly available data from these reports include tabular data on status and distribution, as well as spatial distribution data available at a standard 10-km grid scale. They include the following datasets:

- Article 12 (Birds Directive): Status and distribution from Article 12 reports[164];
- Article 17 (Habitats Directive): Status and distribution from Article 17 reports[165];
- Natura 2000: Distribution of SPAs and SACs designated as part of the EU Birds and Habitats Directives, respectively[166].

Other important datasets that inform the status and/or distribution of biodiversity in the EU include:

- atlas grids
- observation records
- species-range maps
- species-distribution models
- tracking data
- conservation designations
- habitats & vegetation.

These datasets are discussed in more detail in the chapter below.

Atlas grids

Description: Wildlife atlases present systematically collated data on species presence or abundance. Typically, a region is divided into a grid, and each grid cell is surveyed using a standardised protocol that ensures a consistent sampling effort. In some countries, the grid cells follow the latitudes and longitudes - cell intervals of 1 degree, 30 minutes and 15 minutes are often chosen for convenience. In higher latitudes where such an approach leads to grid cells with large differences in area, sizes are more often fixed using grid sizes of 1, 2, 5, 10 or 50 km. When repeated over different time intervals using comparable methodologies, atlases are a very useful way of documenting changes in presence and abundance.

Type: Vector/raster.

Pros: Chart patterns of bird occurrence over large geographic areas. Often consistent sampling effort.

Cons: Gridded data does not often match natural boundaries exactly. Recording effort is often uneven between grid cells. Sometimes it is possible to make corrections for these differences in sampling effort.

Examples:

- The European Breeding Bird Atlas 2 (EBBA2) map contains more than 5,000 50x50 km squares including information on 500+ breeding species[167].
- The Bird Atlas of Britain and Ireland (2007–2011)[168] maps birds in both winter and the breeding season. It is a partnership between the BTO, BirdWatch Ireland, and the Scottish Ornithologists' Club.
- The EMODnet Atlas of Marine Life[169] provides a combination of tools, models and spatial maps that allow users to visualise marine biological data. The Atlas gives an overview of the marine birds, mammals, reptiles, fish, benthos, algae and plankton that occur in European marine waters.
- The European Atlas of Forest Tree Species[170] published by the European Commission is a useful resource on the distribution of trees and forested habitats.

Observation records

Description: Georeferenced species observation records collated through structured surveys or, increasingly, crowdsourced through amateur naturalists. Georeferenced observation records can be mapped as points to show distribution and abundance.

Type: Point.

Pros: Point densities can be interpolated to generate grid or contour maps.

164 https://www.eionet.europa.eu/etcs/etc-bd/activities/reporting/article-12
165 https://www.eionet.europa.eu/etcs/etc-bd/activities/reporting/article-17
166 https://www.eea.europa.eu/data-and-maps/figures/natura-2000-birds-and-habitat-directives-10
167 https://mapviewer.ebba2.info/
168 https://www.bto.org/our-science/projects/birdatlas
169 https://www.emodnet-biology.eu/about-atlas
170 https://forest.jrc.ec.europa.eu/en/european-atlas/

Cons: Potentially unequal distribution of recording effort and therefore high degree of omission error. Techniques exist for adjusting for any differences in sampling effort.

Examples:

- The European Seabirds at Sea (ESAS)[171] database contains at-sea data collected from ships and aircraft using methods described in Tasker *et al*. (1984) and Camphuysen (2004). A strip-transect method with distance bands is used for birds on the sea, and snapshot information is used for flying birds. Data are collected by seabird researchers across north-west Europe and the UK's Joint Nature Conservation Committee (JNCC). The data are managed on behalf of partners by the JNCC. Approximately 3,000,000 counts of seabirds have been collected since 1979. Data are available upon request.
- The open-access eBird Basic Dataset (EBD)[172] includes all raw eBird observations and associated metadata. It is updated monthly and available for download. EBD also contains associated packages for processing this particular data in R (a computer program). Additionally, eBird observational datasets are made available through the Global Biodiversity Information Facility[173].
- The Euro Bird Portal[174] is a project by the European Bird Census Council (EBBC) combining 29 institutions across 21 European countries. This repository aggregates data from multiple sources for large-scale spatial analyses. Currently, data are visible through an interactive web viewer. However, as the EBBC project progresses, third parties will be able to access the data and products directly.
- BirdTrack[175] is a free online portal for submitting bird records for Britain and Ireland.
- Ornithoportal[176] provides bird data for Austria, France, Germany, Italy, Luxembourg, Poland, Spain (Catalonia and the Basque country) and Switzerland.
- Observation.org[177] is a tool for field observers around the world to record and share their plant and animal sightings.
- The European Biodiversity Portal[178] offers access to biodiversity observations and ecological data, along with tools for sharing or discovering data.
- The EMODnet Biology data portal[179] provides free access to data on the temporal and spatial distribution of marine species and species traits from all European regional seas. EMODnet Biology is part of the EU-funded European Marine Observation and Data Network and is built upon the World Register of Marine Species and the European Ocean Biogeographic Information System.

Species-range maps

Description: Species-range maps indicate broad presence or absence, and typically reflect the extent of occurrence (EOO) for a species. Such information can be refined sufficiently with land-cover analyses and species-distribution models to produce more realistic representations of species presence.

Type: Polygon.

Pros: A useful source of data in the absence of observation records or atlas data.

Cons: Typically, such maps reflect EOO, which can result in significant omission error.

Examples:

- The EEA holds GIS data on the distribution of European species and habitat types. These are aggregated by conservation status per Member State and at the EU-28 level.
- BirdLife International compiles and maintains digitised distribution maps for all of the world's bird species. These maps are available through the Integrated Biodiversity Assessment Tool (IBAT).

Species-distribution models

Description: Species-distribution models (SDMs) combine species-observation data with known environmental parameters to create more accurate forecasts of occurrence. SDMs can also be used to model future distributions based

[171] http://archive.jncc.gov.uk/default.aspx?page=4469
[172] https://ebird.org/home
[173] https://www.gbif.org/
[174] https://www.eurobirdportal.org/ebp/en/#home/HIRRUS/r52weeks/CUCCAN/r52weeks/
[175] https://bto.org/our-science/projects/birdtrack
[176] https://www.fauna.hr/
[177] https://observation.org/
[178] http://biodiversity.eubon.eu/
[179] https://www.emodnet.eu/biology

on different scenarios, such as projected climate change or planned species recovery. During the planning process for developments with high longevity, it may be important to anticipate any likely changes in future sensitivity.

Type: Vector/raster.

Pros: More likely than range maps to reflect area of occupancy.

Cons: Accuracy depends on underlying algorithms. Ground-truthing advised.

Tracking data

Description: Data showing successive locations of an animal at specific times and places. The data typically come from tagged individuals (e.g. GPS tags). Tracking data provide important insights into a species' spatial ecology, and can be used to identify key foraging sites or migratory routes. Scientists collect animal-movement data by attaching electronic tracking devices to individual animals. These range from very-high-frequency radio transmitters, which send a signal to a researcher's receiver, to GPS and Argos Doppler tags, which convey more precise time and location data and do not rely on a person to make a physical observation.

Type: Line.

Pros: Useful for identifying migration routes, key foraging sites etc.

Cons: Typically highly variable recorder effort, with strong bias to certain species in certain locations.

Examples:

- Online databases, such as Movebank (hosted by the Max Planck Institute for Ornithology), act as repositories for animal tracking data. Individual series of tracking data are owned by the researchers who can be contacted for data requests.
- The Seabird Tracking Database - Tracking Ocean Wanderers (hosted by Birdlife International) is the largest collection of seabird-tracking data in existence. It serves as a central store for seabird-tracking data from around the world and aims to help further seabird conservation work and support the tracking community.

Conservation areas

Description: Boundaries of areas designated for their conservation importance (protected areas, Natura 2000 sites, Important Bird and Biodiversity Areas (IBAs), etc.).

Type: Polygons/Points.

Pros: Key areas for consideration when planning renewable energy.

Cons: Some datasets costly for commercial use.

Examples:

- The Natura 2000 network of protected sites in the EU consists of SACs, as defined in the EU's Habitats Directive (92/43/EEC), and SPAs, as designated under the EU Directive on the Conservation of Wild Birds. The Natura 2000 network in turn is part of the Emerald network of Areas of Special Conservation Interest under the Bern Convention.
- The Natura 2000 viewer is an online tool that presents: (i) all Natura 2000 sites; (ii) key information on the species and habitats for which each site has been designated; and (iii) population estimates and information on conservation status. See http://natura2000.eea.europa.eu/.
- Natura 2000 data and maps.
- Protected Planet provides extensive, up-to-date information on protected areas globally. It is managed by the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) with support from the IUCN and its World Commission on Protected Areas (WCPA).
- Key Biodiversity Areas (KBAs) constitute the largest and most comprehensive global network of sites that are significant for the global persistence of biodiversity. The World Database of KBAs is managed by BirdLife International on behalf of the KBA Partnership. It hosts data on global and regional KBAs, including Important Bird and Biodiversity Areas (IBAs). Additional information on IBAs in the marine realm can be found through the Marine IBA e-Atlas. In the EU, the IBA inventory has helped inform the designation of SPAs, and the inventory's value as a 'shadow list' of SPAs has repeatedly been recognised by the European Court of Justice and the European Commission.

- For commercial purposes, data from the World Database of KBAs and the World Database on Protected Areas are available through the Integrated Biodiversity Assessment Tool (IBAT).
- Ramsar sites: Further details about sites designated under the Ramsar Convention are available, but there is limited availability of spatial data.

Habitat & vegetation

Description: Depicts ecological communities as they relate to elevation, geology, topography, and soils.

Type: Raster/vector.

Pros: Useful for identifying vulnerable ecological communities.

Cons: Maps are often quite general.

Examples:

- Natura 2000 data viewer shows the distribution of habitats reported under Article 17.
- The CORINE Land Cover inventory was set up by the European Community as a means of compiling geospatial environmental information in a standardised and comparable manner across the European continent. The programme was initiated in 1985, and the first iteration of the data series covered the reference year of 1990 with subsequent releases covering the years 2000, 2006, 2012, and 2018.
- The Ocean Data Viewer offers users the opportunity to view and download a range of spatial datasets, including habitat layers, relating to marine and coastal biodiversity.

Key recommendations

Wildlife-sensitivity maps should be a standard precursor to all renewable-energy plans and development.

Wildlife-sensitivity maps should be developed in close collaboration between all relevant stakeholders including regulatory authorities, wildlife organisations, and developers.

Many Member States will be considering a renewable energy mix that includes elements of wind, solar and other technologies. Ideally, these different renewable energy types should be considered collectively through the same mapping exercise with sensitivity layers developed for each type separately.

Wildlife sensitivity maps should be undertaken at a variety of geographic scales. Planning at a large spatial scale is essential in order to strategically optimise the most appropriate development opportunities both from renewable energy perspective and a nature perspective. Where possible, maps should be developed at a regional, national or even a multinational level. However, finer-scale maps, informed by additional data collection, and targeted at areas of either high development potential or high likelihood of wildlife conflict, should also be considered.

Wildlife sensitivity maps should attempt to cover all potentially impacted species and habitats of conservation concern (inclusion within the EU Nature Directives). Certain taxa will inevitably prove more difficult to assess with limited data on their distribution and incomplete knowledge on how they are impacted. Such groups will require more rudimentary analysis and a more precautionary interpretation.

Where possible, wildlife-sensitivity maps should be designed to be compatible with existing planning tools.

Wildlife sensitivity maps should be publicly accessible, simple and intuitive to use and accompanied with clear interpretative guidance.

Wildlife sensitivity maps should be developed in collaboration with multiple taxonomic experts to ensure the comprehensive compilation of relevant datasets.

Datasets relating to the Natura 2000 network can be used to develop wildlife sensitivity maps in the EU. Data collected in association with Articles 12 and 17, based on a 10 x 10 km grid, can provide a good basis for data generation.

Wildlife sensitivity maps should be developed in such a way that new datasets or updates can readily be incorporated.

Data on broad habitat suitability can be a useful starting point for data deficient taxa. Data (and knowledge on how best to interpret it) is much more limited for certain taxa such as bats and marine mammals.

Wildlife sensitivity maps should utilise the best available data at the finest possible scale. They should clearly indicate levels of uncertainty, data limitations and the comparability of different datasets.

Wildlife sensitivity maps should be compatible with the relevant planning system and be accessible to all relevant users and target groups. Online platforms are a good way to present maps, enabling end user to interactively interrogate the maps and view the layers alongside other variables, such as other development locations, protected sites etc. Face-to-face promotion with planning authorities, developers and other end-users can be valuable in increasing uptake.

APPENDIX E – NATIONAL GUIDANCE IN RELATION TO THE ASSESSMENT OF SIGNIFICANT EFFECTS FROM WIND ENERGY DEVELOPMENTS ON BATS, BIRDS AND MARINE MAMMALS

Table 9-2 National guidance document used for the assessment of significant effects from wind energy developments on bats

Countries	Party (P) or Range (R) State[180]	Type	EUROBATS (N: no; Y: yes)	Unofficial national guidelines exist (N: no; Y: yes)	Officially recommended by authorities (N: no; Y: yes)	Title	Ref
Albania	P	CC	N	N	N		
Georgia	P	OECD	N	N	N		
Israel	P	MENA *	Y	N	N	Carcass survey guidelines (docweb)	
Israel	P	MENA	Y	N	N	Bat and wind turbine assessment guidelines (docweb)	
Macedonia, FYR	P	OECD	N	N	N		
Moldova	P	OECD	N	N	N		
Monaco	P	OECD	N	N	N		
Montenegro	P	CC	N	N	N		
Norway	P	OECD	N	N	N		
San Marino	P	OEC	N	N	N		
Switzerland	P	OEC	N	N	N		
Ukraine	P	OEC	N	N	N		
Belgium	P	MS	Y (Walloon region)	N	Y	Note de référence pour la prise en compte de la biodiversité	http://biodiversite.wallonie.be/servlet/Repository/28103.pdf?ID=28103

[180] 'Range State' in relation to a particular migratory species means: (i) any State (and where appropriate any other Party referred to under subparagraph (k) of this paragraph) that exercises jurisdiction over any part of the range of that migratory species; or (ii) a State, flag vessels of which are engaged outside national jurisdictional limits in taking that migratory species.
'Party' means a State or any regional economic integration organisation constituted by sovereign States which has competence in respect of the negotiation, conclusion and application of international agreements in matters covered by this Convention for which this Convention is in force.
Source: Convention on the Conservation of Migratory Species of Wild Animals via https://www.cms.int/en/convention-text.

Belgium	P	MS	Y (Flanders)	N	Y	Effecten van windturbines op vogels en vleermuizen in Vlaanderen	https://pureportal.inbo.be/portal/files/11928837/Everaert_2015_EffectenVanWindturbinesOpVogelsEnVleermuizenInVlaanderen.pdf
Bulgaria	P	MS	N	Y	N		
Croatia	P	MS	N	?	Y	Report of the IWG on Wind Turbines and Bat Populations (2017)	http://www.zastita-prirode.hr/content/download/393/2127
Croatia	P	MS	N	?	Y	Smjernice za izradu studija utjecaja na okolis za zahvate vjetroelektrana	
Cyprus	P	MS	N	N	N		
Czech Republic	P	MS	Y (with some local adaptations)	N	N		NO (for adaptations)
Denmark	P	MS	N	N	N		
Estonia	P	MS	N	N	N		
Finland	P	MS	N	N	Y	Planning wind-farm construction update 2016 Tuulivoimarakentamisen suunnittelu. Päivitys 2016.	http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79057/OH_5_2016.pdf
Finland	P	MS	N	N	Y	Avian impacts assessment in wind power building Linnustovaikutusten arviointi tuulivoimarakentamisessa.	http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/75407/SY_6_2016.pdf?sequence=1&isAllowed=y
Finland	P	MS	N	N	Y	Impact of wind turbines on avifauna and bats in literature and reports, Kirjallisuusselvitys tuulivoimaloiden vaikutuksista linnustoon ja lepakoihin.	https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/80066/TEMrap_27_2017_verkkojulkaisu.pdf?sequence=1
France	P	MS	Y	Y	Y		Official general guidelines https://www.ecologique-solidaire.gouv.fr/sites/default/files/Guide_EIE_auto%20env_2017-01-24.pdf http://www.grand-est.developpement-durable.gouv.fr/IMG/pdf/Guide_eolien_cle71dfc4.pdf https://eolien-biodiversite.com/IMG/pdf/protocole_de_suivi_revision_2018.pdf http://www.charente-maritime.gouv.fr/content/download/19109/131043/file/12%

							20Eolien%20St%20F%C3%A9lix%205%20annexe%2013%20Protocole_de_suivi_environnemental pdf (2015) SFEPM guidelines pre-survey: http://www.sfepm.org/pdf/20160201_planification_V2.1.pdf (2016) survey: https://www.sfepm.org/pdf/20160213_diagnostic_V2.1.pdf(2016) monitoring: https://www.sfepm.org/pdf/20160213_suivis_V2.1.pdf (2016) la prise en compte des Chiroptères dans la planification des projets éoliens terrestres en France le diagnostic chiroptérologique (étude d'impact) des projets éoliens terrestres les suivis des impacts des parcs éoliens terrestres sur les populations de Chiroptères
Germany	P	MS	N	Y (for several federal states or companies)	Y (for some federal states and a national one on wind turbines in forests)		Bayern: https://www.verkuendung-bayern.de/files/allmbl/2012/01/anhang/2129.1-UG-448-A001_PDFA.pdf (2011) Baden-Wurttemberg: https://wm.baden-wuerttemberg.de/fileadmin/redaktion/m-mvi/intern/Dateien/PDF/Windenergieerlass_120509.pdf (2012) Hessen: http://www.energieland.hessen.de/mm/WKA-Leitfaden.pdf (2012) Niedersachsen part 1: (2016) part 2: http://www.umwelt.niedersachsen.de/download/96712/Leitfaden_-_Umsetzung_des_Artenschutzes_bei_der_Planung_und_Genehmigung_von_Windenergieanlagen_in_Niedersachsen_Ministerialblatt_vom_24.02.2016_.pdf (2016)

							Nordrhein-Westfalen general: https://www.umwelt.nrw.de/fileadmin/redaktion/PDFs/klima/13_11_12_nrw_leitfaden_arten_habitatschutz.pdf (2013) in forests: https://www.umwelt.nrw.de/fileadmin/redaktion/PDFs/klima/leitfaden_wind_im_wald.pdf (2012) Rhineland-Palatinate https://lfu.rlp.de/fileadmin/lfu/Naturschutz/Dokumente/Erneuerbare_Energien/Naturschutzfachlicher-Rahmen-zum-Ausbau-der-Windenergienutzung-RLP_VSW-LUWG_2012.pdf.pdf Saarland: http://www.saarland.de/dokumente/thema_naturschutz/Leitfaden_Artenschutz_Windenergie_Schlussfassung_19Juni2013.pdf (2013) Sachsen-Anhalt: http://www.lee-lsa.de/uploads/media/Leitfaden_Artenschutz_an_WEA_in_ST_07.01.16.pdf(2016) Sachsen-Anhalt https://mule.sachsen-anhalt.de/fileadmin/Bibliothek/Politik_und_Verwaltung/MLU/MLU/04_Energie/Erneuerbare_Energien/Windenergie/181126_Leitlinie_Artenschutz_Windenergieanlagen_barrierefrei.pdf Schleswig-Holstein: http://www.umweltdaten.landsh.de/nuis/upool/gesamt/windenergie/windenergie.pdf (2008) Thüringen: https://www.thueringen.de/mam/th8/tlug/content/arbeitshilfe_fledermause_und_windkraft_thuringen_20160121.pdf (2015) Other: BfN – in forests: http://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/bfn_position_wea_ueber_wald.pdf (2011)

							NLT: http://www.nlt.de/pics/medien/1_1414133175/2014_10_01_Arbeitshilfe_Naturschutz_und_Windenergie__5__Auflage__Stand_Oktober_2014_Arbeitshilfe.pdf (2014)
Germany		MS				Arbeitshilfe Mopsfledermaus Untersuchungs- und Bewertungsrahmen für die Genehmigung von Windenergieanlagen (2018)	https://lfu.rlp.de/fileadmin/lfu/Naturschutz/Dokumente/Erneuerbare_Energien/Arbeitshilfe_Mopsfledermaus_2018_07_23_LfU
Germany		MS				Leitfaden zur Beachtung artenschutzrechtlicher Belange beim Ausbau der Windenergienutzung im Saarland	http://www.saarland.de/dokumente/thema_naturschutz/Leitfaden_Artenschutz_Windenergie_Schlussfassung_19Juni2013.pdf
Germany		MS				Report of the IWG on Wind Turbines and Bat Populations (2017)	http://www.lee-lsa.de/uploads/media/Leitfaden_Artenschutz_an_WEA_in_ST_07.01.16.pdf
Germany		MS				Empfehlungen zur Berucksichtigung tieroklogischer Belange bei Windenergieplanungen in Schleswig-Holstein (2008)	http://www.umweltdaten.landsh.de/nuis/upool/gesamt/windenergie/windenergie.pdf
Germany		MS				Arbeitshilfe zur Berucksichtigung des Fledermasusschutzes bei der Genehmigung von Windenergieanlagen (WEA) in Turingen (2015)	https://www.thueringen.de/mam/th8/tlug/content/arbeitshilfe_fledermause_und_windkraft_thuringen_20160121.pdf
Germany		MS				Windkraft uber Wald (2011)	http://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/bfn_position_wea_ueber_wald.pdf
Germany		MS					http://www.nlt.de/pics/medien/1_1414133175/2014_10_01_Arbeitshilfe_Naturschutz_und_Windenergie__5__Auflage__Stand_Oktober_2014_Arbeitshilfe.pdf
Hungary	P	MS	N	N	N		
Ireland	P	MS	N	Y	N	Bat Conservation Ireland Wind Turbine/Wind Farm Development Bat Survey Guidelines (2012)	http://www.batconservationireland.org/pubs/reports/BCIreland%20Wind%20Farm%20Turbine%20Survey%20Guidelines%20Version%202%208.pdf (2012)
Italy	P	MS	N	N	N		
Latvia	P	MS	N	N	N		
Lithuania	P	MS	Y		Y		
Luxembourg	P	MS	N	N	N		NO
Malta	P	MS	N	N	N		

Netherlands	P	MS	N	Y	N		http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken/windenergie-op-land/milieu-en-omgeving/vleermuizen(2013) https://www.rvo.nl/sites/default/files/2014/02/Protocollen%20vleermuisonderzoek%20bij%20windturbines.pdf (2013) https://www.rvo.nl/sites/default/files/2014/02/Samenvatting%20-%20%20Hoofdrapport%20Windturbines%20and%20bats%20in%20the%20Netherlands%20%28NL%29.pdf (2013)
Poland	P	MS	N	Y (NGOs guidelines 2009 not updated, draft official guidelines recommended by NGOs)	N (draft official guidelines still not officially accepted but commonly used)	Ytyczne dotyczace oceny oddzilywania elektrowni wiatrowych na nietoperze (2013)	http://www.ansee.pl/wp-content/uploads/2015/09/Wytyczne_dotyczace_oceny_oddzialywania_elektrowni_wiatrowych_na_nietoperze.pdf
		MS				Temporary Polish Guidelines for Assessment Of Wind Farm Impacts on Bats	http://www.salamandra.org.pl/DO_POBRANIA/Nietoperze/Guidelines_Poland.doc
Portugal	P	MS			Y	Diretrizes para a consideração de morcegos em programas de monitorização de Parques Eólicos em Portugal continental (2017)	http://www.icnf.pt/portal/naturaclas/patrinatur/resource/docs/Mam/morc/morc-recom-p-eolic (2008) http://www2.icnf.pt/portal/pn/biodiversidade/patrinatur/resource/docs/Mam/morc/2018-03-19-recomendacoes-parques-eolicos-out2017.pdf A draft of a new version (2017) is waiting for approval by the authorities
Romania	P	MS	N	Y	N	18th Meeting of the Advisory committee (2013)	http://www.aplr.ro/index.php?lang=ro&cat=9&page=2
Slovakia	P	MS	N	N	N		
Sweden	P	MS	N	N	N		
UK	P	MS	N	Y	Y	Bats and onshore wind turbines, interim guidance (2014)	http://publications.naturalengland.org.uk/file/6122941666295808
		MS				Bats and Onshore Wind Turbines Survey, Assessment and Mitigation (2019)	https://www.nature.scot/sites/default/files/2019-01/Bats%20and%20onshore%20wind%20turbines%20-%20survey%2C%20assessment%20and%20mitigation.pdf
		MS				Renewable Energy Planning Guidance Note 3 (Cornwall)	https://www.cornwall.gov.uk/media/3626640/3-Onshore-Wind-V2-June-2013-cover.pdf

		MS				Recommended approach for bats and single, small wind turbines in Cornwall	https://www.cornwall.gov.uk/media/3622897/Bat-survey-guidance-for-small-wind-turbine-applications-in-Cornwall-March-2011.pdf
		MS				Ceredigion	https://www.ceredigion.gov.uk/utilities/action/act_download.cfm?mediaid=52666 (2015)
Algeria	R	MENA	N	N	N		
Andorra	R	OECD	N	N	N		
Armenia	R	OECD	N	N	N		
Azerbaijan	R	OECD	N	N	N		
Belarus	R	OECD	N	N	N		
Bosnia and Herzegovina	R	OECD	N	N	N		
Holy See	R	OECD	N	N	N		
Iran	R	MENA	N	N	N		
Iraq	R	MENA	N	N	N		
Jordan	R	MENA	N	N	N		
Kazakhstan	R	MENA	N	N	N		
Kuwait	R	MENA	N	N	N		
Lebanon	R	MENA	N	N	N		
Libya	R	MENA	N	N	N		
Liechenstein	R	OECD	N	N	N		
Morocco	R	MENA	N	N	N		
Palestinian AT	R	MENA	N	N	N		
Russian Fed.	R	OECD	N	N	N		
Saudi Arabia	R	MENA	N	N	N		
Serbia	R	CC	N	N	Y (chapter about wind farms in national EIA guidelines for bats)	Bats and Environmental Impact Assessment	http://www.nhmbeo.rs/upload/images/ove_godine/Promocije2011/bats_and_environmental_impact_assessment_web_lq.pdf (2011)
Spain	R	MS	N	Y	N	Report of the IWG on Wind Turbines and Bat Populations	http://secemu.org/wp-content/uploads/2016/12/barbastella_6_num_esp_2013_red.pdf (2013)
Syria	R	MENA	N	N	N		
Tunisia	R	MENA	N	N	N		
Austria	R	MS	N	N	N		
Greece	R	MS	N	N	N		
Turkey	R	CC	N	N	N		

Table 9-3 National guidance document used for the assessment of significant effects from wind energy developments on birds

Countries	**Title**	**Location**
Finland	Linnustovaikutusten arviointi tuulivoimarakentamisessa	http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/75407/SY_6_2016.pdf?sequence=1&isAllowed=y
Hungary	Szélenergia és természetvédelem	http://www.termeszetvedelem.hu/_user/browser/File/Taj/Szélenergia_és_tv_08.pdf
UK	Onshore wind energy	https://www.nature.scot/professional-advice/planning-and-development/renewable-energy-development/types-renewable-technologies/onshore-wind energy
UK	Bird Collision Avoidance: Empirical evidence and impact assessment	http://jncc.defra.gov.uk/pdf/Report_614_FINAL_WEB.pdf

* MENA: Middle East and North Africa

Table 9-4 National guidance document used for the assessment of significant effects from wind energy developments on marine mammals

Countries	Title	Location
Finland	Tuulivoimarakentamisen suunnittelu	http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79057/OH_5_2016.pdf?sequence=1&isAllowed=y
Germany	Konzept für den Schutz der Schweinswale vor Schallbelastungen bei der Errichtung von Offshore-Windparks in der deutschen Nordsee (Schallschutzkonzept)	https://www.bfn.de/fileadmin/BfN/awz/Dokumente/schallschutzkonzept_BMU.pdf
Netherlands	Kader Ecologie en Cumulatie – 2018 Ondertitel: Cumulatieve effecten van aanleg van windparken op zee op bruinvissen	https://www.noordzeeloket.nl/publish/pages/157579/kader_ecologie_en_cumulatie_-_2018_cumulatieve_effecten_van_aanleg_van_windparken_op_zee_op_bruinvis.pdf
Netherlands	Cumulatieve effecten van impulsief onderwatergeluid op zeezoogdieren	https://www.noordzeeloket.nl/publish/pages/123302/kader_ecologie_en_cumulatie_t_b_v_uitrol_windenergie_op_zee_deelrapport_b_-_bijlage_tno-onderzoek_cu.pdf
UK	Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise	http://jncc.defra.gov.uk/pdf/JNCC_Guidelines_Piling%20protocol_August%202010.pdf
UK	JNCC guidelines for minimising the risk of injury to marine mammals from using explosives	http://jncc.defra.gov.uk/pdf/JNCC_Guidelines_Explosives%20Guidelines_August%202010.pdf
UK	General advice on marine-renewables development	https://www.nature.scot/professional-advice/planning-and-development/renewable-energy-development/types-renewable-technologies/marine-renewables/general-advice-marine

APPENDIX F – BAT COLLISION MORTALITY

Table 9-5 Prevalence of Annex II species (bold text) in mortality records across Europe (of 9,354 casualties recorded between 2003 and 2017).

Order/family	Common name	Species (EUNIS)	Number of casualties in reports
Chiroptera: Miniopteridae	Schreiber's bent-winged bat	*Miniopterus schreibersii*	11
Chiroptera: Pteropodidae	Egyptian fruit bat	*Rousettus aegyptiacus*	0
Chiroptera: Rhinolophidae	Blasius's horseshoe bat	*Rhinolophus blasii*	0
Chiroptera: Rhinolophidae	Mediterranean horseshoe bat	*Rhinolophus euryale*	0
Chiroptera: Rhinolophidae	Greater horseshoe bat	*Rhinolophus ferrumequinum*	2
Chiroptera: Rhinolophidae	Lesser horseshoe bat	*Rhinolophus hipposideros*	0
Chiroptera: Rhinolophidae	Mehely's horseshoe bat	*Rhinolophus mehelyi*	1
Chiroptera: Vespertilionidae	Barbastelle	*Barbastella barbastellus*	5
Chiroptera: Vespertilionidae	Bechstein's bat	*Myotis bechsteinii*	1
Chiroptera: Vespertilionidae	Lesser mouse-eared bat	*Myotis blythii*	7
Chiroptera: Vespertilionidae	Long-fingered bat	*Myotis capaccinii*	0
Chiroptera: Vespertilionidae	Pond myotis bat	*Myotis dasycneme*	3
Chiroptera: Vespertilionidae	Geoffroy's myotis bat	*Myotis emarginatus*	4
Chiroptera: Vespertilionidae	Greater mouse-eared bat	*Myotis myotis*	7

Collectively, they represent less than 0.5% of bat casualties recorded (found both accidentally and during post-construction monitoring studies from 2003 to the end of 2017). The source document[181] notes that these figures reflect 'by no means the real extent of bat mortality at wind turbines' because they are 'based only on reported fatalities to EUROBATS IWG members and not on the effective mortality that is calculated taking into account different sources of biases such as survey effort, the removal of carcasses by predators/scavengers, the searcher efficiency and the percentage of the area really searched'. That aside, Annex II species are clearly at less risk from wind turbines than several other species.

[181] The report of the EUROBATS IWG (Meeting 23) on wind turbines and bats presented to the Advisory Committee: https://www.eurobats.org/sites/default/files/documents/pdf/Advisory_Committee/Doc.StC14-AC23.9_rev.2_Report_Wind_Turbines.pdf

Table 9-6 Proportion of recorded bat casualties at European wind energy developments by species.

Species*	Proportion of wind-farm casualties across Europe
Pipistrellus pipistrellus	24%
Nyctalus noctula	16%
Pipistrellus nathusii	17%
Pipistrellus pipistrellus/pygmaeus	5%
Nyctalus leisleri	8%
Pipistrellus spp.	7%
Pipistrellus kuhlii	5%
Hypsugo savi	4%
Pipistrellus pygmaeus	5%

*The species listed make up over 90% of recorded wind farm casualties across Europe 2003-2017 (percentages exclude those casualties where no identification was made). No other species exceeds 5% of the recorded casualties. All species are Annex IV species, which includes ‘All species’ of Microchiroptera. None of these species are listed on Annex II of the Habitats Directive.

Source: The report of the EUROBATS IWG on wind turbines and bats presented to the 23rd meeting of the Advisory Committee (https://www.eurobats.org/sites/default/files/documents/pdf/Advisory_Committee/Doc.StC14-AC23.9_rev.2_Report_Wind_Turbines.pdf)