Conflict fiche 8: Offshore wind and area-based marine conservation

Over the last decades, awareness of the marine environment and knowledge related to its protection has grown. A range of policy measures have been introduced nationally and internationally, e.g. to reduce pollution, enhance ecological resilience, and ensure the protection of ecosystems, species and habitats. Offshore wind farming is a relatively new activity with various impacts on the marine environment. Much is still unknown about the influence of offshore wind turbines on marine plants and animals. This conflict fiche describes potential conflicts between offshore wind farming and area-based marine conservation and provides ideas for MSP planners for addressing them.

1. Description of the two sectors

1.1. Area-based marine conservation

Marine conservation generally is a huge field of research and policy. Operating at the international, national and sub-national level, it can be broadly differentiated into area-based approaches, as well as approaches that target overall ecosystem health or particular species, such as efforts to reduce pollution or bird protection.

The main tool for area-based marine conservation is Marine Protected Areas (MPAs), but there are other designations that fulfil the same function (such as Natura 2000 areas). There has been a tenfold increase in MPA designations around the world since 20001. At the same time, MPA designation alone does not necessarily mean successful conservation2: Large but wrongly located and managed MPAs may potentially achieve fewer conservation outcomes than a smaller but correctly placed and managed MPAs.

Anthropogenic impacts can reduce the conservation benefits of all area-based approaches to conservation3. Although stringent management rules are sometimes applied, such as total bans on certain activities within MPA boundaries, protected areas are still affected by pressures originating outside of the protected area. This is most obvious in the case of water or noise pollution4. For area-based protection to be effective, it is therefore important that its design and management includes a wide range of stakeholders - including all the sectors that will be affected by, or will

1 IUCN (2017)
2 https://www.cbd.int/sp/targets/, accessed 3 January 2019
3 Amengual & Alvarez-Berastegui (2018)
4 Hossain & Morris (2017)
5 Coomber et al. (2016)
6 Blau & Green (2015)
themselves affect, the protected area.\textsuperscript{7} Furthermore, the mere fact that certain areas are designated does not mean that animals and plants in other areas are not important, e.g. as ecological support areas or feeding or nursery areas, or as a resource for human consumption. It is evident that spatial instruments such as MSP will not be able to achieve the full range of desired conservation benefits for the sea - other agreements and sectoral policy will also need to come into play.

Figure 1: Europe’s regional seas and facts on the European MPA network\textsuperscript{8}

The main categories of marine animals relevant in the context of offshore wind farming are protected species of birds, bats, seals, whales and dolphins both within and outside of protected areas. Fish are also a consideration, either as part of the food chain or as target species for fisheries. These various species require different spaces for foraging, breeding, spawning and migration, including the seafloor, the water column, the water surface and air space. Some are very specific in their requirements, others are more generalist; they also differ widely with respect to their distribution, population and conservation status.

Apart from particular areas for feeding or breeding, the ability to move between areas is particularly important for species (e.g. for migratory species). Sound and echolocation are of key

\textsuperscript{7} Dehens & Fanning (2018)
\textsuperscript{8} European Environmental Agency (2015)
importance to some species. Some marine mammals are very sensitive to noise disturbance, with effects ranging from avoidance of areas to hearing impairment to physical injury.

Conservation is represented by statutory agencies but also many NGOs, such as Bird Life Europe or the WWF. Their drive to be involved in MSP processes is very strong. Apart from public opinion, compliance with legislation plays a strong role in marine conservation. In case of developments with a possible human impact, environmental assessments (SEAs or EIA) need to be conducted and measures taken to reduce potential negative impacts.

1.2. Offshore wind

Offshore renewable energy is the fastest growing sector of the blue economy in Europe, with considerable potential to deliver technological development and job opportunities. Direct employment in the EU more than doubled between 2014 and 2016, rising to about 160 000 and now exceeding total employment in the EU fishing fleet. Strong policy drivers, as well as the continued development of the industry are expected to push offshore wind farming into further growth. The EU Renewable Energy Directive requires the EU to meet at least 20% of its total energy needs from renewables by 2020, to be achieved by attaining individual national targets. Prices for projects to be completed in the next 5 years are lower than previously as a result of the maturing of the industry, improved technology, growing investor confidence, and the introduction and deployment of a new generation of turbines, with enormous swept area and tremendous output.

Developments are particularly strong in the Eastern Atlantic, North and Baltic Sea, but are also beginning in other sea areas. The UK currently has the largest amount of installed offshore wind capacity in Europe, with 40.8% of all installations.

Offshore wind farm-related decisions have consequences in the long term as wind farms have a life span of 25-30 years. It is also a contentious sector as positive and negative externalities can be high. There are conflicts with many other sectors (such as impacts on the safety of navigation, environmental impacts) but also potential synergies, such as artificial reef formation or possibilities for co-location (e.g. mariculture).

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9 Richardson et al. (1998)
10 Wind Europe (2018a)
11 Ibid.
Offshore wind farms have environmental effects during the construction and operation phase. Impacts during the construction phase are mainly related to noise, habitat destruction (including cable laying) and the impacts of increased vessel traffic. Impacts during the operational phase are also related to noise effects, but also due to displacement effects and collision risks (e.g. bird collisions). Operational effects are more locally variable, and there could even be positive ecological effects such as the formation of artificial reefs and a subsequent increase in biodiversity. Presently, there is little information on cumulative impacts and long-term effects of offshore wind farm operation on the food web, as well as on combined effects with other human activities, such as fisheries or shipping. These aspects remain key open issues for sustainable marine spatial planning.\(^1\)

The noise produced by wind turbines when in operation comes from different parts of the turbine. Most noise is produced by interactions between the surface of the blade and the air flowing over it (aerodynamic processes). Mechanical noise also comes from the physical movements of the gearbox, generator, and structure borne parts, which can produce low-frequency noise.\(^2\) Structure-borne parts do not cause a significant increase in noise in shallow water; however, in deep water noise might be observable for distances of 10 km. Higher frequencies tend to reduce themselves within a certain distance, but lower frequencies travel longer. Sound emissions, and

\(^{12}\) Ibid.
\(^{13}\) Bergström et al. (2014)
\(^{14}\) Council of Canadian Academies (2015)

**MSP Platform Conflict Fiche 8: Offshore wind and marine conservation**

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**Table 1: Number of offshore wind farms with grid-connected turbines, number of turbines connected and MW grid-connected at the end of 2017 per country**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NO. OF FARMS</th>
<th>NO. OF TURBINES CONNECTED</th>
<th>CAPACITY INSTALLED (MW)</th>
<th>CAPACITY INSTALLED/DECOMMISSIONED IN 2017 (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>31</td>
<td>1,753</td>
<td>6,835</td>
<td>1,679</td>
</tr>
<tr>
<td>GERMANY</td>
<td>23</td>
<td>1,169</td>
<td>5,355</td>
<td>1,247</td>
</tr>
<tr>
<td>DENMARK</td>
<td>12</td>
<td>506</td>
<td>1,266</td>
<td>-5</td>
</tr>
<tr>
<td>NETHERLANDS</td>
<td>7</td>
<td>365</td>
<td>1,118</td>
<td>0</td>
</tr>
<tr>
<td>BELGIUM</td>
<td>6</td>
<td>232</td>
<td>877</td>
<td>165</td>
</tr>
<tr>
<td>SWEDEN</td>
<td>5</td>
<td>86</td>
<td>202</td>
<td>0</td>
</tr>
<tr>
<td>FINLAND</td>
<td>3</td>
<td>28</td>
<td>92</td>
<td>60</td>
</tr>
<tr>
<td>IRELAND</td>
<td>2</td>
<td>7</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>SPAIN</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>NORWAY</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>FRANCE</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>4,149</td>
<td>15,780</td>
<td>3,148</td>
</tr>
</tbody>
</table>

\(^{12}\) Ibid.
\(^{13}\) Bergström et al. (2014)
\(^{14}\) Council of Canadian Academies (2015)

**Figure 2: Number of offshore wind farms with grid-connected turbines, number of turbines connected and MW grid-connected at the end of 2017 per country**
with these noise that goes into the water column, also increase with greater wind speed at the height of the blades.

During the construction phase pile driving activities are undertaken. This technique requires steel tubes to be inserted up to 30 meters into the seabed. In general, hydraulic pile hammers are used for this purpose. During the erection of a 3.5 m monopile, peak sound pressure levels of more than 180 dB can occur at 1 km distance from the pile driver\textsuperscript{15}. Several measures can be taken to reduce the noise, for example by adjusting the way the piles are put into the ground or by the use of sound barriers, such as bubble curtains. Noise levels can vary quickly, depending on local circumstances, and must be considered in the context of other ambient noise, much of which is also anthropogenic.

Wind turbines then need to be connected to a high voltage substation and the grid, requiring cables to be put in the sea floor. Usually, trenches are cut and cables put into them, and afterwards covered with for example stones.

### 2. Conflict description

Figure 3 gives an overview of the possible impacts of offshore wind farms on the environment. A distinction is made between the construction and operational phase, and different species and habitats.

<table>
<thead>
<tr>
<th>Habitat/species</th>
<th>Construction phase</th>
<th>Operational phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine mammals</td>
<td>Avoidance of areas with underwater noise due to piling</td>
<td>Possible attraction to windfarms due to high food abundance (see fish)</td>
</tr>
<tr>
<td>Seabirds</td>
<td>Disturbance by vessels (avoidance distance 2 km)</td>
<td>Collision risk, avoidance of windfarms, new habitat</td>
</tr>
<tr>
<td>Fish</td>
<td>Disturbance, change and loss of habitat Negative impact on fish eggs and larvae</td>
<td>Decreased fishing and vessel activity leads locally to higher biomass and larger fish</td>
</tr>
<tr>
<td>Benthos</td>
<td>Disturbance, loss and change of habitat of soft substrate species</td>
<td>Higher biodiversity and a higher biomass of hard substrate species, stepping stone for invasive species</td>
</tr>
<tr>
<td>Sandbanks</td>
<td>Disturbance, loss and change of habitat</td>
<td>Loss and change of habitat</td>
</tr>
</tbody>
</table>

*Figure 3: The effects of offshore wind farming on the marine environment\textsuperscript{16}*

\textsuperscript{15} Elmer et al. (2007)
\textsuperscript{16} Royal Haskoning DHV (2017)
2.1. Conflicting elements

Conflicts between offshore wind farming and marine conservation mostly arise on account of noise disturbance and displacement. Specific conflicts include the following:

- **Noise pollution during the construction phase**

Noise disturbance during the construction phase can lead to changes in the behaviour of a range of sea animals. They could avoid the source and be chased out of important areas, for example spawning grounds. They may not be able to detect food or find directions, or their hearing may get damaged at close range. Pile driving can be as loud as 250 decibels at the source and can potentially be picked up by a harbour porpoise over distances of at least 80 km under certain circumstances\(^\text{17}\). Research in Germany and Denmark confirms that porpoises temporary migrate to other areas during pile driving, with potential impacts on fitness and reproduction. However, research also found that population density returns to normal after the pile driving is finished. It is unclear, though, whether the animals returning are the same individuals as the previously disturbed or new individuals that have no knowledge of earlier noise disturbance.

- **Noise pollution during the operational phase**

For some species of offshore seabirds, it has been observed that they tend to avoid areas where OWFs have been constructed. Populations of auks, gannets, tubenoses and divers in the North Sea have decreased after the installation of wind turbines. Bird densities also decreased in neighbouring areas where no new infrastructure was constructed. Location, wind turbine characteristics and spatial configuration of the turbines within the wind farms are possible explanations for this. Birds no longer recognise the area as their feeding area and will move to alternative areas. Although sensitive to low frequency sound and vibration\(^\text{18}\), fish species in general are not heavily influenced by operational noise. Mammals such as porpoises, bottlenose dolphins, Northern Right whale, harbour seals and baleen whales can be disturbed by specific frequencies of underwater noise.

- **Collision**

Thousands of birds are suspected to collide with the rotor blades of offshore wind turbines each year. Precise figures are difficult to obtain as it is not usually possible to count dead birds below the turbines. Monitoring programmes using cameras have started in Germany (Alpha Ventus), England (ORJIP) and the Netherlands (OWEZ/WT-bird), not only to register the number of collisions but also to identify the species involved. The probability of bird collisions depends on locational factors and wind farm design, as well as species behaviour (such as height of flight) and physiology\(^\text{19}\). Bats also

\(^{17}\) European Commission (2016a)  
\(^{18}\) Robinson (2012)  
\(^{19}\) Zwart et al. (2016)
have a large chance to be hit by rotor blades. In the North Sea, swarms of bats have been detected moving between continental Europe and the United Kingdom, passing many offshore wind farms.

- **Other impacts on birds**

European seas are internationally important for a number of breeding and resting seabird populations that are subject to special protection status. Moreover, every year tens of millions of birds cross the North Sea and the Baltic Sea on migration. Apart from collision, the erection of offshore wind turbines may affect birds as follows: (1) short-term habitat loss during construction, (2) long-term habitat loss due to disturbance by turbines including disturbances from boating activities in connection with maintenance, (3) formation of barriers on migration routes, and (4) disconnection of ecological units, such as roosting and feeding sites. Cumulative effects may arise as a result of multiple offshore wind farms being constructed, and in connection with other pressures on birds (such as shipping). Precise impacts are difficult to measure as there is still a lack of good data on migration routes and flight behaviour of many of the relevant bird species\(^{20}\).

- **Ecological damage to the sea floor**

Offshore piling and cable laying also influence the sea floor. Possible effects include changing streams or patterns of erosion, both of which could influence underwater habitats and with this, the availability for food. It is not expected, however, that these effects are severe. For fish and fish larvae, pile driving can have a negative effect, but recent research found these effects to be extremely small\(^{21}\). Concerning the linkages between electromagnetic field due to the grid cables and the migration of selected fish species, only very minor effects have been found.

### 3. Drivers of conflict

The key drivers for the expansion of offshore wind farming are the renewable energy objectives set by Member States. The location of offshore wind farms is mostly driven by cost effectiveness, meaning that a location with low sea depths, short cables and high winds is preferred. Technological advances and cost reductions also act as drivers of conflict as they enable larger turbines to be constructed further offshore over larger areas.

Key drivers for environmental protection and the protection of species and habitats are environmental laws. The Marine Strategy Framework Directive’s Descriptor 11 specifies that “Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment”\(^{22}\). Other drivers are the enlargement of MPAs or other protected areas, as well as species-specific conservation targets at the population level. Although there is increasing

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\(^{21}\) Bolle *et al.* (2014)

\(^{22}\) European Commission (2016b)
understanding about potential negative effects of offshore wind farming on marine flora and fauna, uncertainty remains a key driver of conflict. A precautionary approach may dominate in the absence of sound knowledge. This is particularly the case for cumulative effects of human activities, where offshore wind farming may only be one factor among many.

Public perception may also be a driver of conflict as species protection can be an emotional issue. At the same time, public opinion in many countries is also in favour of renewables, which may increasingly also include offshore wind.

4. MSP solutions

Most adverse effects of offshore wind farms on birds and mammals can be prevented by careful wind farm placement and design. A simple way to mitigate ecological impact is to avoid essential habitats for endangered species, or areas with high abundance of critical species. Some countries for instance prohibit offshore wind farming in Natura 2000 areas. Once location decisions have been made, technical options can be used to mitigate impacts on species during construction and operation. Although many of these are not classic “MSP tasks”, MSP could encourage their application or provide a platform for discussion.

A general issue with respect to MSP solutions in this context is the ongoing uncertainty with regards to scientific evidence. This applies both to establishing management needs and measuring their success. Most countries do not have integrated national policy for conservation and renewable energy (see story 1), delegating many specific decisions to the licensing level. MSP planning decisions such as designating search areas for offshore wind can therefore come into conflict with specific project applications within these areas as a result of EIAs. One of the most important roles for MSP is thus to represent a platform for a more thorough analysis of available data and discussion with consultees, saving time and money and perhaps mitigating the problem before it becomes acute during licensing.

Story 1: Forth and Tay wind farms, Scotland

In 2014, four offshore wind farms were granted consent in the Forth and Tay region – Neart na Gaoithe (450MW), Inch Cape (784MW), Seagreen Alpha and Bravo (1,050MW). The decision by Scottish Ministers to grant the consents was legally challenged by RSPB Scotland, an environmental NGO, based on concerns regarding the cumulative risk to seabird populations from collision and displacement. Bird species of concern included kittiwake, gannets and puffins associated with Special Protection Areas (SPAs) in the region. The case was heard in Court of Session23, Edinburgh

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23 The Court of Session, Scotland’s supreme civil court, sits in Parliament House in Edinburgh as a court of first instance and a court of appeal
In 2015, and the judge agreed with the case put forward by RSPB, concluding that the requirements of the environmental assessment processes were not met, including a failure to consult properly and misuse of appropriate assessment. His ruling noted that while there is dominant public interest in sustainable growth and renewable energy, wind farms must be consented “on the basis of defensible environmental decision-making”, which was deemed not to be the case here. He also concluded that Scottish Ministers were in breach of their EU law obligations by refusing or delaying to classify the Outer Firth of Forth and Tay Bay Complex as a marine special protection area (SPA), and which was therefore not properly considered in the consenting decision. However, the 2015 ruling was subsequently overturned on appeal by the Scottish Ministers and in 2016, the consents were reinstated. The Court ruled that there had been no procedural defect in the Scottish Ministers’ appropriate assessment process, nor was there any breach of relevant regulations. It also found that the earlier judge had acted outside of the capacity of the Court of Review in reaching his decision.

A further attempt by RSPB to appeal was refused in 2017. Since the consents were reinstated, offshore wind technology has improved and the developers are progressing new applications to replace their existing consents, which would enable deployment of larger yet fewer offshore turbines. These new application processes are underway and while the number of turbines will be reduced, there are still concerns regarding the risk to seabirds, particularly considering the declining trends of some species. RSPB Scotland has submitted an objection to the first of these ‘new’ applications in 2018\textsuperscript{24}.

\textsuperscript{24} RSPB (2018)

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This case was (and continues to be) highly complex, with many elements interacting. They relate to at what scale conflicts should be addressed and our ability to predict risk (of negative impact), at different scales. At the policy level, there is a supporting policy environment for development of renewable energy, which in Scotland includes particular emphasis on expansion of offshore wind. This can conflict with environmental policy and conservation objectives in relation to birds. Since national policy is not fully integrated, at present these policy conflicts only come to the fore when specific proposals (based on detailed studies for EIA) are being considered. The higher resolution understanding (of conflicts) which is developed at site level can thus be contrary to that at the strategic level. This can lead to problems when projects are advanced based on the ‘certainty’ provided by government through policy and sectoral planning. At the project level, it is very challenging to predict the likely impacts arising from constructed wind farms and to understand the behaviour of seabird populations over time. Reaching judgements on where impacts are acceptable or not becomes highly subjective and debatable. While there is a tradition of aiming for ‘science-based’ decision-making, there is a limit to how science can inform in this regard. Greater emphasis should therefore be placed on the process by which the judgement is made. Uncertainty should reduce over time as monitoring of effects is undertaken at constructed sites, but such intensive monitoring to yield conclusive results is expensive and will take time.

4.1. Preventative solutions

Solution 1: Use GIS-based sensitivity mapping to avoid essential habitats

Sensitivity maps can help to understand the ecological value of marine areas. In 2014 a new GIS tool, called SeaMaST (Seabird Mapping and Sensitivity Tool), was commissioned by Natural England and the Marine Management Organisation in the United Kingdom, which maps sensitivity of seabirds to the wind farm impacts of collision and displacement in English territorial waters. These sensitivity maps are able to inform marine spatial planners and can be used by developers and statutory agencies alike. The maps provide information on existing knowledge of seabird distribution and the confidence associated with that knowledge for Environmental Impact Assessments and contextualise the significance of potential impacts.

25 Bradbury et al. (2014)

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4.2 Mitigation during construction

Solution 2: Temporarily stop pile driving activities

A common solution is to avoid piling in periods of ecological importance (like spawning). This was implemented e.g. in the Netherlands where the competent authority introduced conditions designed to eliminate any significant effects of “round 2” offshore wind farms in 2009. These conditions were: a) The construction of a maximum of one wind farm a year, and b) a seasonal restriction on pilling activity (construction permitted between 1 July and 31 December). In Belgium there is advice not to pile between January 1st and May 1st.

Solution 3: Reduce the noise of pile driving

Construction of offshore wind-turbine foundations is mostly done by pile driving, using hydraulic hammers. Typically, these hammers consist of a steel ram that weighs between 150 to 200 tons. For maximum efficiency, the ram is released full force onto a pile top to drive it down. In general, there are two main approaches to reduce the noise: 27

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26 WWT Consulting (2014)
27 Elmer et al. (2007)

*MSP Platform Conflict Fiche 8: Offshore wind and marine conservation*
• Adjusting the parameters of the pile stroke. Prolonging the impulse not only reduces the sound level, but also shifts the maximum of the acoustic spectrum to lower frequencies, which are less harmful to marine mammals. This is often done by vibration pile driving.28

• Use of sound barriers, which includes various techniques like the well-known bubble curtain, but also other noise barriers (see Figure 6).

<table>
<thead>
<tr>
<th>Noise mitigation system (provider)</th>
<th>Tested configurations</th>
<th>Number of foundations (piles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Big Bubble Curtain – BBC</td>
<td>Supplied air volume (≤ 0,5 m³/(min*m)), diameter and length of the nozzle hose (length: 400 m – 1.000 m), hole configuration of the nozzle hose, distance to construction site (40 m – 125 m), air feed-in (one- or double sided), ballast chain (inside/outside), pre-laying or post-laying, water depth (10 m to 43 m)</td>
<td>&gt; 150 (300)</td>
</tr>
<tr>
<td>(Hydrotechnik Lübeck GmbH &amp; Weyres Offshore GmbH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Big Bubble Curtain – DBBC</td>
<td>DBBC: distance between nozzle hoses (6 m – one water depth)</td>
<td></td>
</tr>
<tr>
<td>(Hydrotechnik Lübeck GmbH &amp; Weyres Offshore GmbH)</td>
<td></td>
<td>&gt; 150 (300)</td>
</tr>
<tr>
<td>Small Bubble Curtain – SBC (Menck GmbH)</td>
<td>Supplied air volume, hole configuration of the nozzle hose</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Hydro Sound Damper – HSD (OffNoise-Solutions GmbH)</td>
<td>Number and size of HSD elements</td>
<td>&gt; 10 (&gt; 10)</td>
</tr>
<tr>
<td>Noise Mitigation Screen - IHC-NMS (IHC Merwee)</td>
<td>Space between inner and outer tube, additional BBC inside</td>
<td>&gt; 150 (150)</td>
</tr>
<tr>
<td>Cofferdam (Advanced Offshore Solutions ApS)</td>
<td>Space between pile and cofferdam</td>
<td>&lt; 10 (&lt; 15)</td>
</tr>
</tbody>
</table>

Figure 6: Examples of tested and evaluated noise mitigation systems under offshore conditions29

Both methods are mutually independent, meaning when used in combination, they add to each other. An important consideration is the frequency of the sounds which is blocked by the sound barriers. While the main barriers might block high frequency sound, low frequency sounds may continue to spread, affecting animals using these low frequency sounds for echolocation and communication. Another problem is that effective noise mitigation strategies and tools are expensive. Noise reduction measures in a recent developed wind farm in Germany added up to 40 million euro, which makes that costs this can become 15% of the total installation expenses30.

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28 Matuschek & Betke (2009)
29 Ibid
30 Van Rhijn (2017)
Solution 4: Choose other technical solutions to prevent harm to animals or reduce noise emission

The following mitigation measures are used in countries:

- Soft-start implies slowing ramping up the piling power
- Employing marine mammal observers and delaying piling if mammals are spotted: In England, piling cannot commence during periods of darkness, poor visibility, or when the sea state is not conducive to visual mitigation as this impedes the work of marine mammal observers. Piling should not be commenced if marine mammals are detected within the mitigation zone (a radius of at least 500 m) or until 20 minutes after the last visual or acoustic detection.
- Acoustic deterrent devices that emit a sound to initially scare away animals during noisy operations
- Noise thresholds: In Germany for example there is a threshold to piling noise. From the piling onwards, the limit at a distance of 750 m is 160 dB SEL and 190 dB SPLpeak, based on masked TTS levels of harbour porpoises including a safety adjustment.
- Restriction on parallel piling

4.3 Mitigation during operation

Solution 5: Establish multi-use of MPAs and offshore wind

While there are several knowledge gaps in the ecological impact of OWF, knowledge gaps also can be found in the positive effects of OWF on the environment. These synergies can be fostered through multi-use development. Research has stated that the most beneficial placement of an OWF to act as an MPA would be in an area of degradation. OWF installations in the past have been able to restore damaged ecosystems and increase biodiversity almost operating as an MPA unintentionally.

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31 Pondera Consult (2014)
32 Stichting de Nordzee (2013)
33 Karlõõseve et al. (2015)
34 Inger et al. (2009)
**Solution 6: Carry out environmental monitoring**

While the environmental effects are often largely unknown and site specific it is of an added value to develop an environmental monitoring programme of a new wind farm development, analyse the effects and take site specific actions. The monitoring programmes could also provide new insights on the environmental impact for future wind farm development. During the period 1999-2006 a comprehensive environmental programme was carried out in order to evaluate the environmental impact of two of the biggest offshore wind farms in the world situated in Denmark: The Horns Rev Offshore Wind Farm and the Nysted Offshore Wind Farm\(^{36}\). This programme found several impacts on the environment, but also states that appropriate siting of wind farms is an essential precondition for limiting negative impacts on nature and the environment. This means that there is indeed a possibility to engineer on OWF in an environmentally sustainable manner that does not lead to significant damage to nature.

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\(^{35}\) Bergström et al. (2014)

\(^{36}\) Danish Energy Authority (2016)
Solution 7: Develop a strategic ecological research programme

Besides monitoring programmes focusing on specific development sites, several countries have developed more comprehensive ecological research programmes. These programmes have a multi-annual research programme focussing on newest findings and developments, and provide budget for research institutes to conduct the research in the field. The United Kingdom has developed a Strategic Environmental Assessments (SEA) research programme\textsuperscript{37}, which funds a significant number of marine research projects to improve the information base for undertaking strategic assessment and support activity specific consenting. In the Netherlands, the 5 years long WOZEP (Dutch Governmental Offshore Wind Ecological Programme) programme has started in 2016 to fill the knowledge gaps around the ecological effects of offshore wind\textsuperscript{38}.

\textsuperscript{37} DEFRA (2017)

\textsuperscript{38} WOZEP (2016)
Solution 8: Use low cost survey techniques for underwater noise

Monitoring underwater noise can be extremely challenging and the costs of these survey techniques have to be balanced with the added value of gathering this information. However, in recent years, the technology available for monitoring underwater noise and marine mammal presence has improved dramatically, with several affordable and good quality instruments now readily available. This means there are now multiple ways in which surveys can be conducted, depending on individual needs. Most importantly, instruments are now available that allow the monitoring of sound underwater both short and long term, autonomously or from a boat, and allow real-time data transmission to a remote location.59

5. Outlook: Future trends and developments in the sectors (with a view to the likelihood of conflicts arising in the future)

5.1. Future trends in area-based marine conservation

Member States are required to implement measures to achieve Good Environmental Status (GES) in line with the Marine Strategy Framework Directive (MSFD). This includes measures to reduce noise pollution (Descriptor 11). It is likely that this will lead to increasing interest in noise mitigation measures, possibly also the development of new technology.

Research is ongoing into the knowledge of impacts of noise. There is increasing evidence that non-injurious effects can still accumulate at the population level40. Research has found that different sources of anthropogenic noise types can affect a variety of marine species; there is also an increase in the scientific literature on the topic, ranging from more physical interests to ecological impacts of noise, management and policy41. More research is also likely to emerge into the impacts of offshore wind farms on the formation of artificial reefs and the potential benefits of offshore wind farms as de facto nature reserves.

Those calling for increased protection of the marine environment will most likely call for the establishment of more MPAs as well as request re-routes in sensitive areas. Additionally, as Member States are required to implement measures to achieve the Good Environmental Status (GES) of the marine environment, as required by the Marine Strategy Framework Directive (MSFD), is it expected that new measures will be taken by European countries for improving the quality of the marine environment and at the same time reduce impacts on the fragile ecosystems and animals. The future of most MPAs will also see an increasing implementation of the Ecosystem-based Approach (EBA), which will improve their management. Finally, the increasing use of technology and the availability of new instruments will contribute to data collection of endangered species and

39 Pace (2015)
40 Williams et al. (2015)
41 Ibid.
will enable policy-makers and related players to make decisions based on scientific data with the aim to reduce anthropogenic pressures on the ecosystems.

5.2. Future trends in the offshore wind sector

Offshore wind developments in the EU will continue to increase mainly in the Baltic Sea and the North Sea, while the Mediterranean is also expected to have its first developments. According to Wind Europe, the UK offshore market will dominate developments up to 2020\textsuperscript{42} with additional 5.2 GW of grid-connected capacity\textsuperscript{43}.

Larger and more turbines are likely to be built in deeper water, requiring new foundation techniques. Alternatives to pile driving are already available which produce less underwater sound, such as gravity-based structures and suction buckets. There are other concepts which need further technical development (like drilling)\textsuperscript{44}.

Floating wind turbines are of interest for the future development of the sector, especially in the deep-sea areas (i.e. Mediterranean and the Atlantic). These are capable of deployment in waters deeper than 35 metres. As such, they can potentially generate large amounts of energy without the constraints associated with turbines in shallower waters or closer to shore. One difference to fixed foundations is the potential for electro-magnetic fields that may be generated from cables within the water column. Better understanding of this is required to assess potential impacts upon electro-sensitive species and with these fisheries\textsuperscript{45}.

New techniques for noise reduction are also likely to become available, possibly also at lower cost. More research is being carried out into the effects of noise. There is also cooperation on Strategic Environmental Assessments, e.g. in the SEANSE project. The general objective of the SEANSE project is “to develop a coherent (logical and well-organised) approach to Strategic Environmental Assessments (SEAs) with a focus on renewable energy.”

\textsuperscript{42} Wind Europe (2017a)
\textsuperscript{43} Wind Europe (2017b)
\textsuperscript{44} Stichting de Noordzee (2013)
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