REPORT

Assessment of relative impact of anthropogenic pressures on marine species

In relation to Offshore Wind

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Date / initials: 24 January 2020

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</tr>
</tbody>
</table>
1 Introduction

Background
North Seas Energy Ministers have signed a Political Declaration in 2016 on energy cooperation on a voluntary base between the North Seas Countries. One of the four working areas for collaboration is Marine Spatial Planning. Within this working area a sub group (the environmental working group) has the assignment to develop a Common Environmental Assessment Frame work (CEAF). Within CEAF an instrument has been developed for use within formal (and non-formal) EIA/SEA procedures as a way for assessing ecological cumulative effects of plans and projects concerning offshore renewable energy development. The instrument is being tested before finalizing its first version. For testing CEAF the SEANSE project is used. SEANSE stands for "Strategic Environmental Assessment North Sea Energy as an aid for Maritime Spatial Planning". The general objective of the SEANSE project is: to develop a coherent approach to Strategic Environmental Assessments (SEAs) with a focus on offshore renewable energy in support of the development and effective implementation of Marine Spatial Plans. The project is co-funded by the EU (Implementation of the European Maritime and Fisheries Fund Work Programme 2016) and participating countries Denmark, France, Germany, Netherlands and Scotland. It has started in early 2018 and will be finalized in the beginning of 2020.

Aim of this project
Apart from testing the CEAF instrument and calculate potential effects on selected key species of CEAF, the parties collaborating in SEANSE want an indication of the relative contribution of different anthropogenic uses/pressures on these species in comparison to the impact by offshore wind energy development (three scenarios) assessed in the SEANSE case studies. The aim of this project is to draft a qualitative estimate of the (relative) contribution of impacts of prioritized anthropogenic pressures on four selected species relation to windfarm development as described in the scenarios 2023 and 2030. This first attempt to give a qualitative overview can be used in future discussions on elaborating this approach as one of the tools in the CEAF toolbox.

Elaboration
For each of the selected species of CEAF, the effects of two scenarios of windfarm development are calculated with models and methods described in the CEAF project. In the North Sea, the five selected species are also facing other human pressures (including pressures from land-based sources). The scenarios describe the windfarm development in different periods (until 2023, 2024-2030, beyond 2030). Estimates of relative contribution of prioritized pressures are asked for 2023 and 2030, because information on windfarm development and other activities after 2030 is only available for a limited number of countries. Over these periods, other human activities and pressures may also change.

Product
This document provides a general overview of which human pressures (and which activities behind these pressures) have potential impact on the selected species. The following questions will be answered: which pressures are the most important (related to the wind farm development in the scenarios) and how do they work on the species (through what mechanisms). Then a qualitative assessment of their contribution is executed, based on the parameters exposure and sensitivity.
2 Method Description

2.1 Introduction

This Section describes the method used to assess the relative impact of a wide range of anthropogenic pressures on selected marine species, in relation to offshore wind, in the present day, 2023 and 2030.

This is a first attempt to develop a method to assess the impact of activities in the North Sea in relation to offshore wind. The method is developed by the Royal HaskoningDHV project team and tested by applying it on bird species and the harbour porpoise. During this process the method was adapted when new insights occurred. A review was done by experts from the Environmental subgroup. Several bird and marine mammal experts were interviewed to get feedback on the method and on the conclusions.

2.2 Activities and Anthropogenic Pressures

Using an existing study (Piet et al., 2017), activities and pressures that are relevant to the present day in the North Sea have been identified and selected for consideration in this study. A short description of these activities in the present day and the expected future growth/reduction (along with comment on the certainty of each prediction) is given in Section 3.

The pressures identified as being relevant to each activity which are considered in greater detail later in the report are described in Section 3.2.

2.3 Selection of Marine Species

In CEAF the following species were selected to assess the cumulative impact of renewable energy:

- Harbour porpoise (*Phocoena phocoena*): impacts of underwater sound generated by pile driving during construction;
- Black-legged kittiwake (*Rissa tridactyla*; “kittiwake”): impacts of collisions with rotating rotor blades of offshore turbines, of particular interest from the perspective of the UK and Norway;
- Lesser black-backed gull (*Larus fuscus*): impacts of collisions with rotating rotor blades of offshore turbines, of particular interest from the perspective of continental NW Europe;
- Red-throated diver (*Gavia stellata*): impacts of habitat loss (i.e. disturbance and displacement) among seabirds due to the presence of operational offshore wind farms; and
- Common guillemot (*Uria aalge*; “guillemot”): impacts of habitat loss (i.e. disturbance and displacement) among seabirds due to the presence of operational offshore wind farms.

2.4 Estimating the Impact Level of Anthropogenic Activities

The mechanism of each relevant pressure is described by activity for each species in Section 5. Using the available information in the literature, an estimate is made of the present day exposure and sensitivity of each species to each activity as per the definitions provided in Table 2-1 and Table 2-2. For exposure, the value assigned is a reflection of a range of parameters, including the area occupied by an activity in the marine environment, the permanence (or otherwise) of the activity and whether the activity is seasonally restricted, how numerous such activities are with respect to location across the wider North Sea, along with the temporal and spatial overlap with the species in question. For sensitivity, much of the assessments are based on what is known about the effect of particular activities/pressures on each species taken from the literature. To enable this approach to cover all activities/pressures that need to be included in this report, the definitions are intentionally broad.
Following this, exposure and sensitivity are combined into the matrix to give an approximate level of impact, as shown in Table 2-3. This is used to form an approximate level of impact of a particular activity/pressure on a particular species. The matrix forms the basis of impact assignment, and where appropriate this is refined using expert opinion based on the relevant literature presented.

Table 2-1. Exposure levels and definitions used in assessment.

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Broad Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Frequently or continually exposed to activity/pressure</td>
</tr>
<tr>
<td>Moderate</td>
<td>Sometimes exposed to activity/pressure</td>
</tr>
<tr>
<td>Low</td>
<td>Infrequently or never exposed to activity/pressure</td>
</tr>
</tbody>
</table>

Table 2-2. Sensitivity levels and definitions used in assessment.

<table>
<thead>
<tr>
<th>Sensitivity Level</th>
<th>Broad Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Effect of activity/pressure is consistent, and results in mortality (directly or indirectly) or behavioural changes that lead to substantial reductions in breeding success and/or survival</td>
</tr>
<tr>
<td>Moderate</td>
<td>Effect of activity/pressure is less consistent than &quot;High&quot;, and results in behavioural changes that whilst not likely to be directly responsible for extensive mortality, can lead to less substantial reductions in reduced ability to use a habitat/area for a particular purpose, breeding success and/or survival</td>
</tr>
<tr>
<td>Low</td>
<td>Effect of activity/pressure is negligible or non-existent</td>
</tr>
</tbody>
</table>

Table 2-3. Matrix used to combine sensitivity and exposure to give an approximate level of impact.

<table>
<thead>
<tr>
<th>Sensitivity/Exposure</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Very Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Based on the assessment of exposure and sensitivity the total level of impact is determined per activity. The relative contribution of all activities that cause the pressure is then assessed in relation to the approximate level of impact from offshore wind in the summary. It is estimated whether the activity has more, similar or less impact on the marine species than offshore wind in the present day. This is a subjective process based on expert opinion, which has been formed through the literature review presented in Section 5. The outcome was discussed during the interviews with experts. The five categories used for the relative impact are as follows:

- Considerably more than offshore wind;
- More than offshore wind;
- Similar to offshore wind;
- Less than offshore wind; and
- Considerably less than offshore wind.

### 2.5 Estimating Anthropogenic Impact Levels in the Future

In Section 6, the future development of the relative contribution of all activities is assessed. This is a subjective approach based on the total estimated impact levels determined in Section 5, the development in activities as described in Section 3 and the estimated volumes of the activities in relation to offshore wind for the present day and the future scenarios in Table 6-1.

The five impact categories are the same as the process for assessing present day impacts of activities relative to offshore wind, which is described in Section 2.4.
2.6 Methodological Limitations

Whilst this study is designed to provide a guide to the relative estimated impact levels of the activities listed in Section 3 on the species listed in Section 2.3, there are a number of limitations which readers of this document should consider when interpreting the information presented:

- The scope of this project is to consider the impacts on the five selected species at the North Sea level. A downside of this approach is that more local trends are not fully considered (e.g. variation in the abundance of prey species, leading to variation in breeding success at different colonies/regions). Whilst these are considered in the text accounts where availability of research allows, a single impact level must still be estimated for each species and activity.

- Similar to bird species, the more regional and local trends of harbour porpoise relatively high abundance areas (such as Dogger Bank), and the seasonal movement trends of the species across the North Sea, and the relative exposure of each industry in respect of those seasonal movements, are not fully considered.

- It is recognised that for some species covered by the report (e.g. red-throated diver and kittiwake), their annual cycle means they spend a large amount of time outside the North Sea during particular seasons. Both species will also be subject to a range of activities/pressures at this time.

- Similarly, there are substantial pressures on some species that are not immediately attributable to any particular anthropogenic activity, which are not considered by the report. For example, invasive alien species have a very large effect on many seabird populations (Dias et al., 2019), and many indirect effects of certain pressures (e.g. increased predation of breeding adult birds and chicks by other seabirds which may increase with reductions in prey availability).

- Following on from this, it should be noted that the levels of impacts of a particular activity on a particular species are not exactly the same in all situations across the North Sea, both spatially and also temporally. Where possible the literature review has prioritised research that provide evidence of trends across the entire geographical area of interest. Where this is not possible, or where it is considered to strengthen the review, research focusing on specific colonies or regions is also used. Whilst effort has been made to incorporate temporal trends in activities into assessments, due to the level of detail required this has not been possible for all activities.

- In the case of some pressures (e.g. prey availability), a range of activities are acting on them simultaneously. Isolating the relative contribution of each activity is a difficult task with considerable uncertainty attached to the conclusions.

- There is a considerable level of uncertainty attached to a range of predictions contained within this report. These encompass the level of sensitivity of a particular species to an activity/pressure, the level of exposure of a particular species to an activity/pressure on a species, the predicted growth/reduction in activities/pressures in the future, and the fact that multiple pressures are likely acting on a species at the same time, making the assignment of impact magnitudes by activity difficult at times. Where possible, IPCC guidance is applied in terms of assigning descriptors to particular levels of likelihood (IPCC, 2010).
3 Anthropogenic Activities and Pressures Included in Study

3.1 Anthropogenic Activities

3.1.1 Offshore Wind

The offshore wind energy industry in the North Sea is constantly evolving with new advancements in technology allowing larger wind farms to be built further offshore that use bigger and more powerful turbines than current models. In 2017 approximately 10GW of offshore wind was in operation in the North Sea (GWEC, 2017). It is expected that in 2023 around 23 GW of offshore wind farms will be in operation. In the period after 2023 it is predicted based on current market predictions that another 27 GW (approximately) will be built, which means that in 2030 around 60 GW will be in operation (SEANSE scenario’s).

Figure 3-1 Installed and planned wind farms by 2030 in the North Sea

3.1.2 Shipping

Approximately 90% of the world’s trade is done by ships. With over 7,600 ships passing annually through hotspot areas of the North Sea region, it is one of the busiest shipping grounds in the world, only behind the South China Sea. Most shipping occurs in the shipping lanes, though there are many exceptions. The shipping sector is still affected by the financial crises of 2008, and together with the low level of global growth currently predicted, growth in shipping is likewise predicted to be slow in the coming years¹. There is also the potential that the opening of the Arctic to shipping in the future will increase shipping within the North Sea, but there are many uncertainties associated with that possibility. For this report it is therefore assumed that shipping will be on the same level in 2023 and moderately increased in 2030.

The likelihood of the 2023 scenario is higher (“very likely” (90-100% probability) than the 2030 scenario (“about as likely as not” (33-66% probability)), as there is considerable uncertainty surrounding the prediction of economic conditions between the present day and 2030.

¹ https://northsearegion.eu/media/4836/northsee_finalshippingreport.pdf
3.1.3 Oil and Gas Exploitation

Domestic production in Europe is set to decline as reservoirs in shallow waters are in decline, existing fields are mature and are not being replaced (JRC, 2015), though it is possible that new field development could occur in the future. As the sector ages, decommissioning of oil and gas infrastructure will become increasingly active, with over 200 platforms forecasted for complete or partial removal, nearly 2,500 wells to be plugged and abandoned and 78,000 km of pipeline to be decommissioned in the North Sea between 2017 and 2025. The activities associated with this industry are predicted to remain at the current level in both 2023 and 2030 as increased decommissioning offsets reduced production.

As there seems to be a low probability of governments reversing their commitment to decarbonisation and the meeting of climate targets, and as decommissioning is unavoidable, it is expected that the prediction for 2023 is “very likely” (90-100% probability), and “likely” (66-100% probability) for 2030.

3.1.4 Sand and Gravel Extraction

The demand for sand and gravel is expected to increase due to future large infrastructure and land reclamation projects planned across Europe. Amongst Belgium, Denmark, Germany, the Netherlands, Sweden and the United Kingdom are differences in the need for extraction materials. Belgium, for example, predicts a significant increase with regards to their annual extraction amount whereas the other countries expect little change (Anonymous, 2019), though whether this will occur in existing areas or new ones is unclear. It is assumed that the activity will be on the same level in 2023 and moderately increased in 2030.

Due to a lack of information, and the differing predictions of requirements across different countries, the likelihood of the 2023 and 2030 predictions being correct is considered to be “about as likely as not” (33-66% probability).

3.1.5 Ocean Renewable Energy

For the purposes of this report, wave, tidal and marine solar technologies are grouped under the term “Ocean renewable energy”.

Besides offshore wind, Ocean renewable energy is expected to play an important role in European energy generation beyond 2020, though at the time of writing, commercial deployment remains virtually negligible. According to Ocean Energy Europe (OEE), industry scenarios indicate that up to 337 GW of wave and tidal energy capacity could be deployed around the world by 2050, of which a third is predicted for Europe. It is expected that the deployment of these technologies will increase substantially in the marine environment in the North Sea in the near future (ICES, 2019). There are also plans to build solar panels in the North Sea, in Belgium and the Netherlands. However, there are substantial technological difficulties faced by developers as the industry and its technologies are still immature. It is assumed that this activity will moderately increase in the period up to 2023, with large increases in deployment potential possible by 2030.

The likelihood for both predictions is “about as likely as not” (33-66% probability) based on the uncertainty surrounding commercial viability of existing devices and projects.

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3 https://northsearegion.eu/northsee/o-energy/offshore-renewable-energy-industry-outlook-2030-and-beyond/
3.1.6 Military

The North Sea is used for military activities such as artillery exercises, flight exercises, clearance of historic ammunition dumps and mine disposal. It is presumed that as these activities represent national security interests there is very little information available on them, with the exception of the demarcation of large subtidal areas in which they can occur. It is assumed that these activities will not change in the period before and after 2023.

As there is currently no known reason for military activities to increase or decrease substantially compared to existing levels, these predictions are considered to be “likely” (66-100% probability).

3.1.7 Aquaculture

An analysis of aquaculture production in the EU since 2000, based on FAO Fisheries Information system (FIGIS), shows that aquaculture production in the EU has fallen by approximately 8% since 2000, from 1.4 million tonnes in 2000, to 1.28 million tonnes in 2013. All EU Member States have set targets to increase aquaculture production, with variable target dates—production is projected to increase to approximately 1.76 million tonnes by 2025, representing an annual growth rate of 2.7% (Aquaspace, 2017).

Aquaculture in the North Sea is developing from fish towards seaweed and mussel cultivation, predominantly in coastal waters. In addition, the possibilities of multiuse of offshore wind farms is being researched. It is assumed that this activity will moderately increase in the period before and after 2023.

It is expected that the prediction for 2023 is “very likely” (90-100% probability), and “likely” (66-100% probability) for 2030.

3.1.8 Land-based Sources

Contaminant concentrations from land-based sources have continued to decrease in the majority of areas assessed, especially for polychlorinated biphenyls (PCBs). Although concentrations have not yet reduced to background levels (Anonymous, 2019). The extent of eutrophication in the OSPAR Maritime Area has continued to improve since 1990, but the concerns about atmospheric and riverine inputs of nutrients identified in OSPAR’s Quality Status Report 2010 remain. Marine litter, in particular plastic, is abundant on beaches, in the water column and on the seafloor (QSR, 2010). At the moment there is a lot of attention for the marine litter problem worldwide, so it can be expected to decrease in the coming years but on the other hand the production of plastics tends to increase. It is hard to say what will happen with contaminants and eutrophication, so it assumed that it will not change in the period before and after 2023.

The likelihood of this prediction is considered to be “about as likely as not” (33-66% probability).

3.1.9 Fisheries

Fishing activities are very widespread in the North Sea in the present day and are executed with a variety of techniques and gear. The price of fuel, the price of the fish, the relationship between the setting of quotas and sustainability, and technical innovations all have the potential to strongly influence future development or decline in this industry. There is no clear trend data available for fishing activities for the periods before and after 2023, and it is therefore considered that predicting it is not possible. In the absence of any information it is assumed that fishing levels will not change in the period before and after 2023 relative to the present day.

The likelihood of this prediction is considered to be “about as likely as not” (33-66% probability).
3.1.10 Offshore Islands

There have been several ideas and preliminary plans for building offshore islands as a power hub for offshore wind. At the moment there are no offshore islands or firm plans for their development, though a feasibility study was identified during research for this project (TNO, 2019). Denmark is considering an artificial island in the North Sea. It is considered that there will be no change in 2023 compared to the present-day scenario, and a possibility of a small increase in offshore island deployment by 2030.

The likelihood of the predictions occurring is considered to be “about as likely as not” (33-66% probability) for 2023 and 2030.

3.1.11 Climate Change

Whilst not an anthropogenic “activity” as such, climate change is a significant contributor to a wide range of ecological changes that are ongoing worldwide. As the changes are thought to occur over the long term, the impact of climate change is assumed to be similar in 2023 the present day and increasing in 2030. The likelihood of the predictions occurring is considered to be “likely” (66-100% probability) for both scenarios, though it is noted that ever increasing emissions will accelerate climate change.

3.1.12 Summary

The predicted estimated development of the different activities is presented in Table 3-1., along with associated likelihoods. It does not tell anything about the volume of the increase/decrease, a comparison between activities is not possible based on this table. In Table 6-1 the volumes of the activities in relation to offshore wind for the present-day and the future scenarios are estimated, based on Table 3-1..

Table 3-1. Development in activities from present day by 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>2023</th>
<th>Likelihood 2023</th>
<th>2030</th>
<th>Likelihood 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>&gt;</td>
<td>Very likely</td>
<td>&gt;&gt;</td>
<td>Likely</td>
</tr>
<tr>
<td>Shipping</td>
<td>=</td>
<td>Very likely</td>
<td>&gt;</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Oil &amp; gas exploitation</td>
<td>=</td>
<td>Very likely</td>
<td>=</td>
<td>Likely</td>
</tr>
<tr>
<td>Sand and gravel extraction</td>
<td>=</td>
<td>About as likely as not</td>
<td>&gt;</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>&gt;</td>
<td>About as likely as not</td>
<td>&gt;&gt;</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Military</td>
<td>=</td>
<td>Likely</td>
<td>=</td>
<td>Likely</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>&gt;</td>
<td>Very likely</td>
<td>&gt;</td>
<td>Likely</td>
</tr>
<tr>
<td>Land based sources</td>
<td>=</td>
<td>About as likely as not</td>
<td>=</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Fisheries</td>
<td>=</td>
<td>About as likely as not</td>
<td>=</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Offshore islands</td>
<td>=</td>
<td>About as likely as not</td>
<td>&gt;</td>
<td>About as likely as not</td>
</tr>
<tr>
<td>Climate change</td>
<td>=</td>
<td>Likely</td>
<td>&gt;</td>
<td>Likely</td>
</tr>
</tbody>
</table>

Legend

- Decline: <
- Remains the same: =
- Moderate increase: >
- Strong increase: >>
3.2 Pressures from Anthropogenic Activities

The pressures that result from the activities discussed in Section 3.1 that are considered relevant for the remainder of this report are:

- Underwater noise;
- Bycatch;
- Collision risk;
- Disturbance and displacement;
- Prey availability;
- Pollution/contamination.

There are some pressures which are not considered relevant either to particular activities or species, either due to no pathway of effect, or because whilst a pathway is present, it is not considered to have a substantial effect on the species concerned. These are not included in Section 5 but are included in Table 3-2 for completeness.

<table>
<thead>
<tr>
<th>Species</th>
<th>Pressure</th>
<th>Activity</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour porpoise</td>
<td>Underwater noise</td>
<td>Aquaculture, land-based sources, and cables and pipelines</td>
<td>While it is possible that some of these activities (such as aquaculture and cables and pipelines) may generate underwater noise, it will be to a very localised and low level, and there will be limited impact to harbour porpoise at the noise levels expected. Land based sources will not generate underwater noise.</td>
</tr>
<tr>
<td></td>
<td>Bycatch</td>
<td>All except fisheries</td>
<td>No industry, except for fisheries, has the potential to cause by-catch in harbour porpoise.</td>
</tr>
<tr>
<td></td>
<td>Collision risk</td>
<td>Aquaculture, land-based sources, cables and pipelines, and climate change</td>
<td>While it is possible that some of these activities (such as aquaculture and cables and pipelines) may have the potential for collision risk with harbour porpoise, it will be very limited, with very low potential to cause impact to the harbour porpoise population. Land based sources and climate change will not generate have the potential for increased collision risk.</td>
</tr>
<tr>
<td></td>
<td>Displacement</td>
<td>Shipping, military, aquaculture, land-based sources, and cables and pipelines</td>
<td>While it is possible that displacement effects (habitat loss and loss of harbour porpoise prey species) could occur from these activities, it is not expected that the displacement effects would be significant, either from the low level of activity across the North Sea or due to limited displacement impacts that these activities would have.</td>
</tr>
<tr>
<td></td>
<td>Prey availability</td>
<td>Shipping, oil and gas exploration activities, aquaculture, ocean renewable energy, pollution sources, military activity, offshore islands</td>
<td>No mechanism by which large scale effects considered likely are predicted to occur within the timeframe included within the report (i.e. present day to 2030)</td>
</tr>
<tr>
<td></td>
<td>Bycatch</td>
<td>All pressures except fisheries</td>
<td>No mechanism by which large scale effects considered likely are predicted to occur within the timeframe included within the report (i.e. present day to 2030)</td>
</tr>
<tr>
<td>Species</td>
<td>Pressure</td>
<td>Activity</td>
<td>Details</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Collision risk and disturbance and displacement</td>
<td>Climate change, pollution sources, offshore islands</td>
<td>No mechanism by which any effects considered likely are predicted to occur at any time</td>
</tr>
<tr>
<td>Seabirds</td>
<td>Disturbance and displacement</td>
<td>Military, aquaculture, ocean renewable energy</td>
<td>Whilst displacement events due to such infrastructure is possible, actual impacts are expected to be very small due to the low exposure of seabirds to these activities</td>
</tr>
<tr>
<td></td>
<td>Collision risk</td>
<td>Fisheries, shipping, sand and gravel extraction, military activity</td>
<td>Whilst collision events with such infrastructure is possible, actual numbers of impacts are expected to be very small due to the low sensitivity of seabirds to collision with slow moving/stationary objects</td>
</tr>
</tbody>
</table>

Some pressures (introduction of hard substrate and seabed pressure) are not relevant because they do not have a direct effect on the selected species or cannot be related to offshore wind. These pressures will not be considered further.
4 Marine Species

4.1 Harbour Porpoise

4.1.1 Population Status

Harbour porpoise is the most commonly sighted cetacean in the North Sea (Reid et al., 2003; Wildfowl and Wetlands Trust (WWT) 2009; ASCOBANS 2012; Hammond et al. 2013, 2017). A series of large-scale surveys for cetaceans in European Atlantic waters was initiated in summer 1994 in the North Sea and adjacent waters (SCANS 1995; Hammond et al., 2002) and continued in summer 2005 in all shelf waters (SCANSII 2008; Hammond et al., 2013). Despite no overall change in population size between the SCANS-I and SCANS-II surveys, large scale changes in the distribution of harbour porpoise were observed between 1994 and 2005, with the main concentration shifting from north eastern UK and Denmark to the southern North Sea. Such large-scale changes in the distribution of harbour porpoise are likely the result of changes to the availability of principal prey within the North Sea (SCANS-II, 2008).

The North Sea population of the harbour porpoise is estimated at the number of 345,000 in 2016 (Hammond et al., 2017), the population has been stable in the last decennia. There has been an estimated 0.8% (95% CI: -6.8% to 9.3%) per year from 1994 to 2016, based on the SCANS survey estimates. This estimated trend is not statistically different from zero, and therefore it is considered that the North Sea harbour porpoise population is stable (OSPAR, 2017a). See Figure 4-1 below for a graph to show the population estimate from 1995 to 2016, from the SCANS surveys.

![Figure 4-1 trend line of harbour porpoise abundance estimates in the North Sea (data taken from Hammond et al., 2002, Hammond et al., 2013 and Hammond et al., 2017) (OSPAR, 2017a)]
The baseline environment of the Southern North Sea has been influenced by the oil and gas industry since the 1960s, fishing by various methods for hundreds of years and the construction and operation of offshore windfarms for over ten years. The baseline will continue to evolve as a result of global trends which include the effects of climate change.

The harbour porpoise is protected under the Habitat Directive Annex IV and under OSPAR and ASCOBANS.

4.1.2 Seasons Present

The seasonal harbour porpoise density maps developed by Gilles et al. (2016), as can be seen in Figure 4-2, indicate that in spring, there are higher density areas in the southern and south-eastern part of the North Sea. In summer, there was an apparent shift, compared to spring, toward offshore and western areas. In autumn, there were lower densities compared to spring and summer, and the distribution was spatially heterogeneous.

While it is possible that some of these activities (such as aquaculture and cables and pipelines) may generate underwater noise, it will be to a very localised and low level, and there will be limited impact to harbour porpoise at the noise levels expected. Land based sources will not generate underwater noise.

![Figure 4-2 Expected harbour porpoise densities in the North Sea during spring, summer and autumn (Gilles et al., 2016).](image)
4.2 Kittiwake

4.2.1 Population Status

Kittiwake is on the IUCN Red List (IUCN, 2018), and is categorised as “Vulnerable” (BirdLife International, 2019a). It was first included in this category in 2016. The European population of kittiwake is thought to consist of between approximately 3,460,000 to 4,410,00 mature adults. Numbers of kittiwake have declined rapidly over the past several decades, and there is no evidence that this decline is likely to stop. The current rate of population decline is estimated to be approximately >40% over three generations (i.e. 39 years) (Berglund and Hentati-Sundberg, 2014; IUCN, 2018). Whilst this overall decline is very large (due to large declines and consistent breeding failures in many historical strongholds, such as the UK (Mitchell et al., 2018b, 2018a), reflected in its red-listed status in the UK (Eaton et al., 2015)), there are differences in the rates of decline between populations, whilst some are stable or have increased.

4.2.2 Seasons Present

Birds are most abundant in European waters during the breeding season (approximately March to August (Cramp and Simmons, 1983)). Breeding adults are most frequently associated with coastal colonies, with a mean maximum foraging range of 60km from the colony (Thaxter et al., 2012), though birds may also utilise more distant habitats (as well as more frequently using habitats closer to colonies). Non-breeding and immature birds inhabit shallow, continental shelf waters during the breeding season (Furness, 2015). During the non-breeding season, birds breeding in Europe are distributed throughout the North Sea and Atlantic Ocean, with immature and juvenile birds often travelling further from breeding grounds (Wernham et al., 2002).

4.3 Guillemot

4.3.1 Population Status

The common guillemot is currently categorised as “Least Concern” (BirdLife International, 2019b). The global population trend appears to be increasing. There are variations between different populations, with some faring better than others, and others declining. In the UK, guillemot (along with other species that are able to exploit large proportions of the water column) seem to have bred more successfully in recent years than birds restricted to surface feeding (Mitchell et al., 2018a) The population estimate in Europe is 2,350,000 to 3,060,000 mature adults.

4.3.2 Seasons Present

Birds are generally present in Europe in relatively large numbers all year round, with adults generally being dispersive from breeding colonies outside the breeding season rather than fully migratory (Furness, 2015; Wernham et al., 2002), though there are likely to be local variations. The breeding season occurs between approximately March and July when breeding adults are associated with coastal colonies, with a mean maximum foraging range of 84km from the colony (Thaxter et al., 2012), though birds may also utilise more distant habitats (as well as more frequently using habitats closer to colonies). The distribution of immature and non-breeding birds during this time is not well understood, though it is known that immature birds may spend the winter further from breeding sites than adults (Wernham et al., 2002).
4.4 Lesser Black-backed Gull

4.4.1 Population Status

Lesser black-backed gull is currently categorised as “Least Concern” (BirdLife International, 2019c), with an increasing global population trend. However, this varies between different populations, with some experiencing increases whilst declines are apparent in others, such as the UK (Mitchell et al., 2018a; Nager and O’Hanlon, 2016). Whilst there is no current European population estimate available for this species from BirdLife International, it is described as being “very large”.

4.4.2 Seasons Present

Once considered to be a fully migratory species (Cramp and Simmons, 1983), present day lesser black-backed gull passage behaviour is more variable. For those individuals that do migrate, autumn movements begin in around mid-July each year (Furness, 2015), with large numbers of birds from all over Europe spending the winter in Southern Europe and Africa. Birds return to breeding locations throughout March and April (Wernham et al., 2002). Relatively large numbers of birds that breed in the UK may remain there during the non-breeding season, which may be a response due to increased food availability as much as changes to climate (Banks et al., 2007).

4.5 Red-throated Diver

4.5.1 Population Status

Red-throated diver is currently described as “Least Concern” (BirdLife International, 2019d). Whilst it is recognised that the population is currently decreasing, its “very large” current size and relatively slow rate of population decline mean that the species does not currently reach thresholds to be classified as “Vulnerable”.

4.5.2 Seasons Present

Red-throated divers breed at freshwater pools that are generally located close to the coast and rely on commutes to the sea for feeding. During the non-breeding season, they are coastal birds, spending the entire season at sea (Furness, 2015), with largest numbers found at sheltered coasts. The breeding season is completed in September and October, though many birds leave their breeding grounds in August (Wernham et al., 2002). Autumn migration occurs between September and mid-December depending on location (Furness, 2015). Return migration occurs between February and April (Furness, 2015).
5 Estimation of Present-Day Anthropogenic Activity Impact Levels

In this Section the impact of anthropogenic pressures of activities in relation to offshore wind are estimated for the current situation. First the exposure and sensitivity of the species for the relevant pressures are described and the total level of impact is determined per activity. Based on the total level of impact the relative impact is determined in the summary, by estimating whether the activity has more, similar or less impact on the marine species than offshore wind in the present day.

5.1 Harbour Porpoise

5.1.1 Underwater Noise

Underwater noise impacts on harbour porpoise is a strong area of research and has been for a number of years. Due to this, there is a high level of robust information available of the subject, and a high level of agreement that there are considerable impacts to harbour porpoise as a result of underwater noise. However, there is less certainty and agreement in how exactly harbour porpoise are impacted by different types of noise exposure, and to what level they are impacted. In particular, there is uncertainty in what impact that underwater noise sources may have on the population as a whole. There is relatively high confidence in the following assessments, however it should be noted that the exposure level of each activity does not take into account the difference in harbour porpoise densities across the North Sea (i.e. some areas with high levels of industry may have low densities, which would somewhat reduce the exposure level).

Underwater noise can have detrimental effects on harbour porpoise, as they rely on sound for communication, foraging and travelling. Assessing the potential for an effect on marine mammal species takes into account the source sound characteristics (i.e. frequency, how loud it is, and how continuous (or impulsive) the sound is), how far that sound will travel (dependant on environmental factors such as water depth), and how it relates to known thresholds of effect for marine mammal species. Sound levels decrease with increased distance from the source, meaning that the closer to the source an animal is, the higher the sound level they will be exposed to, and therefore the more serious the effect could be. These are known as ‘Zones of Influence’ (ZoI) (as described by Richardson et al., 1995 and adapted below from McGregor et al., 2013), with the smaller zones having the potential for more significant effects to harbour porpoise (e.g. death or physical injury; and permanent auditory injury (permanent threshold shift (PTS)), and the larger outer zones being a less of a significant threat to harbour porpoise (e.g. temporary auditory injury (temporary threshold shift (TTS)); behavioural effects, such as disturbance and displacement; and masking of sound, e.g. limiting communication, foraging or ability to detect vessels, etc.). Below is a diagram of each of these ZoIs (Figure 5-1), alongside an indication of the industry that could cause these effects to harbour porpoise.
There are two types of underwater noise (impulsive and non-impulsive sound sources) which can have different impacts on harbour porpoise. Impulsive sound sources are typically characterised by brief sounds with a sudden onset and a high peak pressure and are caused by activities such as Unexploded Ordnance (UXO) clearance, impact pile driving, sonar from military exercises and activities, and air guns used for seismic surveys (Piet et al., 2017). Non-impulsive (or continuous) sounds are generally characterised as having a slow onset and are continuous or occur over a longer duration. Non-impulsive sound sources are associated with activities such as shipping, dredging, sand and gravel extraction, operational wind turbines and operational oil and gas platforms (Piet et al., 2017). In general, impulsive sound will become non-impulsive over time and distance from source, as the sound wave ‘smooths’, and in the far field will have the characteristics of a non-impulsive sound (Hastie et al., 2019).

5.1.1.1 Sensitivity to Underwater Noise

The potential for the death of harbour porpoise is included in the table below as it is possible from activities that cause very high levels of impulsive noise, such as UXO clearance, unmitigated. However, there is a requirement that such impacts are mitigated for, and in reality, there is no evidence to suggest that the death of a harbour porpoise has been directly caused by high noise levels (including from UXO clearance). Death is not expected to be caused directly from non-impulsive noise sources, as the noise levels are not considered to be high enough. While it is possible for both PTS and TTS to be caused by non-impulsive sources (it has been reported for construction vessels and dredging activities) it is less common, due partly to harbour porpoise being more sensitive to higher frequency sounds which are more common from impulsive sources such as piling. Masking effects are not expected to occur from impulsive noise sources, as it is thought that marine mammals would be able to communicate during periods of no noise. This is not possible for non-impulsive noise sources, and masking is therefore one of the impacts of most concern to harbour porpoise, as it reduces the ability of individuals to hear any biologically relevant signal, whether by predator, prey or other harbour porpoise.

As well as physical and direct behavioural response impacts, high levels of noise can also cause indirect effects to a population by affecting the ability of individuals to forage in certain areas, altering their vital rates. Modelling of the potential population effects of offshore wind development in the North Sea, as a result of disturbance of harbour porpoise from underwater noise due to offshore wind impact piling, found that, the construction of 65 offshore wind farms had no population effects, with no observed reduction in population levels for observed disturbance distances from an offshore wind farm development. A population level effect

![Figure 5-1 Zone of Influence model for impacts to harbour porpoise from underwater noise, including an indication of the activities that may cause each impact.](image-url)
was only discernible if the disturbance distance was increased to 20 or 50 km (Nabe-Nielsen et al., 2018). However, a similar study (Heinis et al., 2019) using a different model found that, for the currently known offshore wind farms within the North Sea, by 2023 there is a 50% chance that the harbour porpoise population will have declined by approximately 1%, in 2030 it will also be approximately 1%, and by 2044 (the end of the modelling period) there is a 50% chance that the population will have reduced by 2%. These predictions amount to an estimated population loss of 4,994 individuals by 2031, and 6,248 by 2038.

To allow for a comparison of underwater noise sources in the North Sea, activities that generate underwater noise have been split based on the potential to generate impulsive or non-impulsive sound. The table below (Table 5-1) indicates the potential to cause each ZoI effect as outlined above; this is the sensitivity of harbour porpoise to each activity. Activities that generate impulsive sound tend to be temporary in nature, while non-impulsive sound sources can have a longer duration or are more permanent, and therefore represent a constant exposure and long-term impact.

The potential for impact from fish finders has not been included in this review, as the area affected by these are very small, and would be in the area directly underneath the vessel only. It is also expected that any harbour porpoise in the area would be disturbed due to the vessel noise, and therefore would not be present directly beneath the vessel in order to be at risk of impact from the fish finder.

**Table 5-1. Comparison of impulsive and non-impulsive sound sources, and the potential for direct impact on harbour porpoise, without mitigation measures**

<table>
<thead>
<tr>
<th>Potential effect</th>
<th>Impulsive sound sources – potential for effect?</th>
<th>Non-impulsive sound sources – potential for effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Offshore wind (UXO, piling)</td>
<td>Ocean renewable energy (UXO)</td>
</tr>
<tr>
<td>Death</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Permanent Injury</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Temporary Injury</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Behavioural response</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Masking</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Zone of audibility</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Offshore wind farm development in the North Sea produces both impulsive sound (from pile driving) and non-impulsive sources (such as operational noise, and construction or operational activities such as cable laying, dredging, and vessel noise). The potential impacts from offshore wind farm development impulsive sources include auditory injury and behavioural effects (from UXO clearance and impact piling works). The impact on harbour porpoise from all other activities relative to offshore wind farm development is shown in subsequent sections.

The impulsive noise from the oil and gas industry is due to seismic surveying. These types of surveys typically use an array of geophysical survey devices (such as airguns), and while the noise from an individual airgun may not be that high, arrays typically have between 12 and 48 airguns, and when in operation the array can produce significant noise levels, to the same level (in some cases higher) than the noise that is
associated with the piling of offshore wind turbine foundations. A further difference in the impacts from pile driving and seismic surveys is timing; offshore wind farm pile driving tends to have a longer break in piling between foundations, providing a period of recoverability, than seismic surveys, which may be near continuous, with short breaks of a few hours only.

5.1.1.2 Exposure to Underwater Noise

The exposure level of harbour porpoise to underwater noise from each of these activities relates to how much of the activity is present within the North Sea, and how often harbour porpoise could be 'exposed' to each of these activities. In order to determine the exposure level of harbour porpoise from each of the impulsive sound sources, the OSPAR Impulsive Noise Registry has been used, including data from 2014 to 2018 (although it should be noted that the 2018 data is not completed for all EU member states) (ICES, 2019; OSPAR, 2019). This dataset ‘counts’ the number of days for which an impulsive noise was generated per ‘pulse block’ within the North Sea, noting the source of the impulsive noise (e.g. seismic airguns, pile driving, etc.) and the level of noise in a scale from very low to very high. It should be noted that while this dataset is useful in determining which activity has the potential to cause the highest impulsive noise exposure level, the dataset is not complete for all years, and therefore there may be missing data. The relative exposure of each non-impulsive activity is based on the known level of activity within the North Sea.

For impulsive noise, the impulsive noise registry data shows that a total of 10% of all impulsive noise reported in the North Sea is from piling works (none of which is characterised as having a high or very high source level, with 13% of all North Sea impulsive noise being defined as having a medium noise level, and 13% being low or very low in noise level).

For non-impulsive noise, there are approximately 478 vessels capable of supporting the renewable energy sector within the North Sea, including dredging, cable laying vessels and jack-up barges, that would produce non-impulsive noise sources (Navigant Consulting, 2013). Operational noise from wind turbine generators also have a low level of continuous noise, however this is considered to be low in comparison to other sources of noise, although it will be present throughout the operational period of the wind farm. A comparison of the level of non-impulsive noise sources from each industry in the North Sea is based on the known number of vessels or other equipment that could produce those non-impulsive noise sources.

5.1.1.3 Summary of Underwater Noise Impacts

The potential for effects from UXO clearance have not been included within these comparison tables as it is an activity that may be required for all marine activities, and therefore is the same across all industries. Although it should be noted that within the offshore wind farm context of the UK, the clearance of UXO represents a significant proportion of the noise emitted, due to the large number of devices being detonated. This, however, is not the case for other North Sea countries, such as the Netherlands, where it is the sole responsibility of the military to clear these devices from the seabed. Table 5-2 summarises the resultant exposure and sensitivity of each activity.

<table>
<thead>
<tr>
<th>Underwater Noise Activities</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impulsive sources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>High</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td>Offshore islands</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Military</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Low</td>
<td>Very low</td>
</tr>
</tbody>
</table>
It should be noted that the impact of offshore wind farm construction using impact pile driving on the harbour porpoise population is inclusive of any mitigation measures and guidelines that are a current requirement for each EU member state. It is assumed that these requirements and restrictions will be present in each relevant EU member state for future developments.

A summary of the relative levels of impact for each industry in relation to offshore wind is provided in Section 5.1.6. The activity that is considered to have the highest level of impact (due to impulsive noise) is oil and gas, having more of an impact than offshore wind, primarily from the large number of seismic surveys that are undertaken in the North Sea. The activity that the highest impacts form non-impulsive (continuous sources of noise) is shipping, which has been determined to have a considerably higher impact than offshore wind; this is primarily due to the significantly high levels of shipping that take place in the North Sea, and that the noise associated with the industry is constant; shipping has permanently changed the soundscape of the North Sea. Fisheries has also been assessed as having more of an impact than offshore wind, again, primarily due to the high exposure level to noise from both fishing vessels and fish finders. Ocean renewable energy, military and offshore islands have all been assessed as having less of impact than offshore wind, due to the lower exposure level from all activities.

5.1.2 Bycatch

There is a high level of agreement that bycatch is the pressure that is having the biggest impact on the North Sea harbour porpoise population. However, there is limited evidence to support that conclusion. There are similar uncertainties in the expected population level effect to harbour porpoise as a result of offshore wind farm development. The evidence that is available is summarised below, along with the limitations of each source. It is considered, that while there is limited evidence, there is high agreement that the impact of bycatch is considerably worse than any other industry, including offshore wind, and the conclusions of this assessment reflect that.

The biggest cause of mortality for all cetacean species is from the entanglement and by-catch in fisheries equipment, and harbour porpoise are sensitive to by-catch, especially caused by set gill nets (Bjørge et al., 2013; Peltier et al., 2016). An assessment of the threat to harbour porpoise across the Greater North Sea has been undertaken using data on incidentally caught and killed individuals, as reported by the fisheries industry (OSPAR, 2017b). The result of this is that an estimated 1,235 to 1,990 harbour porpoises are by-caught every year (estimate from 2013); or an estimated 0.36-0.58% of the most recent North Sea population estimate of 345,373 (Hammond et al., 2017). However, it is noted that this is likely to be an underestimate due to fishing efforts from small vessels and from recreational vessels not being represented. A much larger bycatch estimate for harbour porpoise within the North Sea has been reported within the harbour porpoise North Sea conservation plan, with a reported estimate of approximately 6,160 individuals, or 1.8% of the North Sea harbour porpoise population (ASCOBANS, 2004; Vinther & Larsen, 2002; Flores
In addition, stranding’s data can be used to estimate the number of individuals reported to have died as a result of bycatch compared to other causes. Around the UK, an estimated 15-20% of stranded harbour porpoise that were examined post-mortem (77-110 individuals) were estimated to be fatally injured by bycatch events, as recorded through the stranding’s database between 2011 and 2017 (Deaville et al., 2018). Within Belgian waters, similar levels of bycatch are recorded through stranding’s scheme data, with a total of 27% of all necropsied harbour porpoise (eight individuals) showing signs of bycatch in 2017 (DG Environment, 2018). In the Netherlands, bycatch numbers were reported as 20% of all stranded individuals (11 individuals) in 2017 (Ministry of Economic Affairs, Agriculture and Innovation, 2018).

Modelling of the potential population effects of offshore wind development in the North Sea as a result of disturbance and displacement of harbour porpoise from underwater noise due to impact piling (and the resultant impact to harbour porpoise vital rates), found that, the construction of 65 offshore wind farms had no population effects, with no observed reduction in population levels for observed disturbance distances from an offshore wind farm development. A population level effect was only discernible if the disturbance distance was increased to 20 or 50 km (Nabe-Nielsen et al., 2018). However, a similar study (Heinis et al., 2019) using a different model found that, for the currently known offshore wind farms within the North Sea, by 2023 there is a 50% chance that the harbour porpoise population will have declined by approximately 1%, in 2030 it will also be approximately 1%, and by 2044 (the end of the modelling period) there is a 50% chance that the population will have reduced by 2%. These predictions amount to an estimated population loss of 4,994 individuals by 2031, and 6,248 by 2038. While this may seem high, it is considerably less than the current annual estimate of 6,160 due to bycatch provided above. It should also be noted that this model included a relatively low adult survival rate of 0.85 to take into account the effect of bycatch.

### 5.1.2.1 Sensitivity to Bycatch

The sensitivity level is defined by the potential impact of these activities on the North Sea population (in this case, this is assessed on the level of population loss expected from each of the activities), based on the literature review above.

The harbour porpoise North Sea population is very sensitive to a reduction in population levels as a result of bycatch and will likely be reduced if current levels continue (Nabe-Nielsen et al., 2014). A population annual loss rate of 4% would have a significant impact on the population levels, and it has been estimated that the bycatch rate needs to be kept below 1.0% annually, in order for the harbour porpoise population to be maintained at more than 80% of the carrying capacity (ASCOBANS, 2000). Efforts at increasing and stabilising harbour porpoise population levels within the North Sea should therefore focus on the reduction of bycatch, rather than the level of anthropogenic noise (Nabe-Nielsen et al., 2014).

### 5.1.2.2 Exposure to Bycatch

The exposure of harbour porpoise to bycatch is defined by the level of activity in the North Sea. The method of commercial fishing that can cause bycatch of harbour porpoise is primarily by gillnet fishing, as well as drift or fixed nets, which forms a small proportion of the total North Sea fisheries industry. Within the UK, large gillnet vessels amount to less than 1% of the total fishing fleet, while smaller drift or fixed net vessels amount to 5% of the total fishing vessels (Calderan & Leaper, 2019). Within the UK part of the North Sea, gillnet fishing is mostly undertaken along the East Anglian, Kent and south England coastlines, and to the north of Shetland. Across the North Sea, it has been estimated that approximately 3% of the fisheries industry is gillnet, which is reducing. In the Dutch North Sea gillnets also tend to be closer to the coast (Piet et al., 2017).
In 2016, approximately 10,000,000 kW days at sea were recorded for static and gillnet fisheries across the North Sea, compared to the total estimate of 160,000,000 kW days from all fisheries industries in the North Sea (ICES, 2018). Figure 5-2 shows the distribution of the mW fishing hours across the North Sea, specifically for gillnet fisheries.

![Figure 5-2 Spatial distribution of average annual fishing effort (mW fishing hours) in the Greater North Sea during 2014–2017 (ICES, 2018)](image)

5.1.2.3 Summary of Bycatch

Table 5-3 summarises the resultant exposure and sensitivity of each activity. It is important to remember that the comparison is done on the overall population loss that each activity has on harbour porpoise, as it has been determined that is the best way to compare the overall impact to the population from these two industries, where they have very different resultant effects.

<table>
<thead>
<tr>
<th>Bycatch</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Fisheries</td>
<td>High</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>

A summary of the relative levels of impact for each industry in relation to offshore wind is provided in Section 5.1.6. There are considerable uncertainties and assumptions made in both the estimations of annual bycatch rates across the North Sea, and the population level effects due to the offshore wind industry in the North Sea. However, what is considered to be widely agreed, is that bycatch is the largest threat to the population, and therefore the conclusion is that bycatch has a higher impact to the population level of harbour porpoise in the North Sea than for what is currently predicted for offshore wind farms.

5.1.3 Displacement

The displacement of harbour porpoise relates to a pressure or activity that creates a movement of harbour porpoise away from that area, such as a reduction or loss of prey species in an area, or a change in seabed habitat or seabed disturbance, as well as the introduction of hard infrastructure. While displacement of harbour porpoise wouldn’t have a direct impact on the harbour porpoise itself, it may have indirect effects...
through a reduction in prey availability, or exclusion from important breeding or feeding areas. Displacement (particularly loss of prey) has the potential to have population level impacts to harbour porpoise through changes to their vital rates, however, this is an ongoing area of research, and while there is agreement that at a certain level of displacement, a harbour porpoise population would start to decline, there is less agreement on what that level is for each activity. The following assessment is therefore based on a high-level review of the potential displacement impacts from each activity in the North Sea.

Displacement could also occur due to underwater noise effects; however, this is included in the assessment above in Section 5.1.1 and has therefore not been further included in the assessment of displacement.

The key impact to harbour porpoise from displacement is the change in prey availability. It is expected that the resultant effect on the harbour porpoise population is low, due to the wide-ranging nature of the species, and the wide range of prey species which are both available to harbour porpoise, and the large distributions of those prey species across the North Sea.

The effects of climate change on harbour porpoise populations are still relatively unknown, however, it is expected that there will be impacts to the population through prey depletion and range shifts. It is well understood that a harbour porpoise habitat and population range is determined from their preferred prey availability, and therefore a change in prey range has the potential to cause a displacement of harbour porpoise (Evans & Bjorge, 2013; Ransijn et al., 2019). It is considered to be likely that, as seas warm, harbour porpoise may shift their range north, following their prey. In recent years a shift southward of harbour porpoise has been noted within the North Sea (Hammond et al., 2017), and it is possible that this was due to a loss of sandeel availability in the northern parts of the North Sea (Evans & Bjorge, 2013; Sveegaard et al., 2012).

5.1.3.1 Exposure to Displacement

The exposure of harbour porpoise to displacement from each of the activities is defined by the level of activity in the North Sea (as defined above), taking into account the level of hard infrastructure that is introduced from each activity (such as platforms in the oil and gas industry) and the permanence of those structures (i.e. will they be removed during decommissioning).

Industries such as fisheries and sand and gravel extraction are expected to impact on the seabed through their operation, impacting on habitats of prey species, and fisheries cause significant displacement through loss of prey species. Bottom fishing techniques, such as benthic trawling etc can cause damage to the seabed, which has the indirect effect of habitat loss for harbour porpoise. The effect that fishing has on the seabed is calculated from the hours fished, the average fishing speed and the gear width. Figure 5-3 below shows the resultant disturbance to seabed habitats from the fishing techniques as an annual average from 2014 to 2017, with the value indicating how many times the seabed would have been ‘swept’ by fishing gear. Surface abrasion indicates damage to seabed surfaces only, while subsurface abrasion relates to penetration into the seabed, or disturbance to the substrate beneath the seabed surface.
A number of industries include the construction of hard infrastructure on the seabed, such as Ocean renewable energy (wave, tidal and solar) and oil and gas projects, while fisheries and sand and gravel extraction have the potential to cause damage to the seabed. For some activities, such as oil and gas and renewable, much of the impact relates to underwater noise rather than construction of infrastructure on the seabed, that noise will have an impact on harbour porpoise prey species, and therefore the level of exposure will be the same as included above.

It should also be noted that much of the offshore wind farm development to date has been in the southern parts of the North Sea. Sandeels, herring and sprat often form important components of harbour porpoise prey intake, and so the future movements of harbour porpoise through the North Sea are likely to be directly related to the effect of climate change on those species. In the period from 2005 to 2016, the highest density areas of herring have moved southwards, while the highest density areas of sprat have moved slightly north (Ransijn et al., 2019). Similar patterns may be observed in the future, although there are still too many unknowns to draw meaningful conclusions on the potential impact of climate change on the distribution of harbour porpoise prey species, and therefore the potential displacement of harbour porpoise, and what the resultant effect would be on the harbour porpoise population. Although there remain many unknowns of the effects of climate change on harbour porpoise, it is known that the impact will increase in the future and could be a significant effect on the population (Ransijn et al., 2019).

### 5.1.3.2 Sensitivity to Displacement

The sensitivity level is defined by the potential impact of displacement for harbour porpoise (in this case, the sensitivity of harbour porpoise is considered to be the same from all activities, i.e. any displacement event will result in the same impact on harbour porpoise, which is potential loss of prey species, or exclusion from key breeding areas).
Offshore wind farm development in the North Sea has the potential to cause displacement to harbour porpoise through a change in habitat, and a change in harbour porpoise prey availability. It is expected that the level of displacement on the harbour porpoise population will be directly related to the level of activity and the amount of hard infrastructure construction for each industry. Offshore wind farm developments introduce a considerable level of hard infrastructure to the seabed, but as the seabed is generally expected to recover after construction activities have completed (as is the case for cables) or once structures are removed during decommissioning (as is the case for the substations and wind turbine generators) any displacement impacts are expected to be either temporary or long-term, with no permanent effect on the harbour porpoise population.

### 5.1.3.3 Summary of Displacement Impacts

Table 5-4 below summarises the resultant exposure and sensitivity of each activity.

<table>
<thead>
<tr>
<th>Displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Fisheries</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Sand and gravel extraction</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Offshore islands</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Climate change</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

A summary of the relative levels of impact for each industry in relation to offshore wind is provided in Section 5.1.6. The only activity that is expected to generate more displacement impact to harbour porpoise than offshore wind is from fisheries, both due to the impact to the seabed (and therefore harbour porpoise habitats) and through the reduction in prey availability. All other activities are expected to have either a similar displacement impact or less than offshore wind.

### 5.1.4 Collision Risk

#### 5.1.4.1 Introduction to Collision Risk

There is some evidence to suggest that harbour porpoise are susceptible to collision risk, however there is a level of disagreement on how likely harbour porpoise are to be at risk of collision, as they are shy animals and tend to avoid large vessels. The evidence that is available on collision risk is presented below, but it should be noted that while collisions have been included, the number of instances are relatively small and it is likely to be the lest impactful pressure included in this report. There is also a great deal of uncertainty in the potential for collision risk from Ocean renewable energy (wave and tidal turbines), and an assessment of this potential source of collision risk has not been possible.

The increasing size of commercial shipping fleets and the increasing number of ferries and recreational vessels in the North Sea means there has been an increase in ship strike for harbour porpoise within the North Sea (Evans et al, 2011). A ship strike has the potential to cause serious injury and death for harbour porpoise. The North Sea has over 400,000 vessel movements per year, with 'hotspots' of very high vessel presence, such as the Strait of Dover and the Keil Canal (Evans et al., 2011). Over the last 20 years, the number of shipping movements, the size of vessels and the vessel travelling speeds have all increased (OSPAR, 2010).
5.1.4.2 Sensitivity to Collision Risk

Although all types and sizes of vessels can pose a risk of collision for harbour porpoise (also for other activities like sand and gravel extraction etc.), it is the vessels travelling at 14 knots or more and of more than 80m in length that tend to cause the most severe and lethal injuries (Evans et al., 2011). Of 2,686 stranded harbour porpoises around the coast of the UK, 537 were investigated at post-mortem, with a cause of death determined for 516 individuals between 2011 and 2017, of which 10 individuals were identified to have died from vessel collision, with a further 33 of unknown physical trauma which could be attributed to vessel strike (Deaville et al., 2018). This leads to an estimated 2-8% of the harbour porpoise population being fatally injured by vessel collisions within UK waters.

The sensitivity level is defined by the impact of collision risk for harbour porpoise. In this case, the sensitivity of harbour porpoise is considered to be the same from all activities, i.e. any collision will result in the same impact on harbour porpoise, which is serious injury or fatality, with the exception of wave and tidal energy developments due to the many unknowns and uncertainties.

Exposure to Collision Risk. The potential for fatal collision of harbour porpoise from each of these industries is directly related to the exposure to vessels or infrastructure that has the potential to cause collision risk, such as vessels and wave or tidal turbines. Therefore, the level of effect of offshore wind collision on harbour porpoise, in relation to other industries in the North Sea, is dependent on the number of those vessels or devices in the North Sea. As noted above, it has been estimated that there are 478 vessels relating to the offshore wind industry present in the North Sea. All other activities are assessed in relation to that number.

The exposure of harbour porpoise to collision from each of these activities is defined by the level of activity in the North Sea (as defined above).

5.1.4.3 Summary of Collision Risk

The level of potential collision risk from wave and tidal energy developments on harbour porpoise is currently unknown. The potential risk of collision from a wave or tidal development will depend on the specifics of the project, including the density of harbour porpoise in the area, the water depth of the site (for bottom deployed devices), and the design, number and location of the energy devices. However, if there is the potential for any significant collision risk with wave or tidal arrays it is expected that effective and adequate mitigation measures would be put in place to reduce the level of perceived risk. This activity has therefore been assessed as having an unknown collision risk.

A summary of these levels of impact for each industry is provided in Section 5.1.6. Collision risk is expected to be considerably higher than offshore wind from the shipping industry, this is due to the large number of vessels present in the North Sea. Both the fisheries and the oil and gas industry have been assessed as having more of a collision risk than from offshore wind, again due to the high number of vessels associated with these industries.

Table 5-5 summarises the resultant exposure and sensitivity of each activity.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Shipping</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Fisheries</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
A summary of the relative levels of impact for each industry in relation to offshore wind is provided in Section 5.1.6. Collision risk is expected to be considerably higher than offshore wind from the shipping industry, this is due to the large number of vessels present in the North Sea. Both the fisheries and the oil and gas industry have been assessed as having more of a collision risk than from offshore wind, again due to the high number of vessels associated with these industries.

### 5.1.5 Pollution

#### 5.1.5.1 Introduction to Pollution Impacts

There is a large degree of uncertainty on impacts to harbour porpoise from pollutants, and where those pollutants originate from. The below assessment provides a short literature review for all known pollutant impacts within the North Sea, however, due to the high level of uncertainty, and the low level of information available of these impacts, a full assessment of the contribution of each pressure has not been possible to do. While there is low evidence available, it is widely agreed that certain pollutants can cause serious impact to harbour porpoise populations.

Contamination refers to the presence of substance that would not naturally occur, while pollution is when contamination results in an adverse biological effect. Contamination therefore doesn’t always mean pollution effects will occur in a population (Chapman, 2007). Pollutants that may have detrimental effects on harbour porpoise include heavy metals (such as lead and mercury), persistent organic pollutants (POPs), such as DDT and polychlorinated biphenyls (PCBs), and dioxins (by-products of industry) (Bollmann, 2010). POPs and dioxins are highly stable and to a large extent are non-degradable, can be transported over long distances and accumulate in the marine environment. Other events that may cause pollution effects on harbour porpoise include chemical or oil spills through blow outs, ship leaks and ship groundings, chemicals that are discharged from vessels and other industry and plastic, contaminant release from the detonation of UXO, anti-bio fouling agents from offshore constructions, as well as micro-plastics and other marine litter (including ghost fishing gear).

New forms of persistent toxic compounds of non-natural origins were identified in the last 20 years, that were previously undetectable. These included polyfluorinated compounds (PFCs), mainly used in the textile industry. While relatively low levels were released into the marine environment (4,500 tonnes per year) compared to other pollutants, PFCs are highly bio-accumulative (Bollmann, 2010).

The bioaccumulation in harbour porpoise can cause disruptions to the endocrine system, cause cancer and other genetic effects, and weaken the immune system (Bollmann, 2010). Top-predators, such as harbour porpoise, are susceptible to exposure to pollutants (including micro-plastics) through accumulation from the ingestion of lower prey species. Figure 5-4 below shows an example of bioaccumulation in a marine mammal species, indicating how much higher the level of pollution within an individual can be in the highest trophic levels.
There is a risk to harbour porpoises that an increase in pollutant levels could impact on the reproduction rate and success (Murphy, 2009). One of the key effects of increased pollutant levels on harbour porpoises is that a breeding female will pass on all contaminants to their calf through lactation, with the potential for the death of the calf. It is also possible that a calf will be aborted through levels of pollution within the female being too high for its survival (Murphy, 2009). If high levels of contaminants are passed on to calves, then fatality of that calf is possible, and has been recorded (Murphy, 2009). Historic pollutants (such as PCBs) that are no longer discharged, but continue to be present in the marine environment, have the potential to cause effects to harbour porpoise populations. It should be noted that although PCBs (and other POPs) have been banned for a number of years, marine environment levels are declining very slowly due to their limited reactivity and are still found in harbour porpoise at concentrations that are known to cause detrimental effects. For example, harbour porpoise stranded around the UK coastline were significantly more likely to have high levels of PCB exposure if they stranded due to infectious disease rather than due to physical injury (Jepson et al., 2005).

Most of the marine litter enters the seas from land-based sources, such as sewage related from rivers, wind-blown from landfill sites near the coast, and a small amount from littering on the coastlines. Shipping also contributes to marine litter, by waste being dumped at sea from both commercial and leisure vessels (Bollmann, 2010). One of the biggest marine litter contributors is from ghost fishing gear (this is gear that has been left at sea, if it is no longer needed or broken). Within the English Channel, it has been estimated that there are between 10 and 100 pieces of marine litter per km² (Bollmann, 2010). Ghost fishing gear can cause entanglement of marine mammal species, and as it is made of predominantly very hard plastics, it doesn’t degrade for up to 600 years, while other marine plastics, particularly micro-plastics, can be ingested by harbour porpoises, either directly or through their prey (Bollmann, 2010). Micro-plastics are created by the break-down of larger bits of plastics into much smaller fragments.
Micro-plastics (of <5mm in size) have the potential to cause impact to harbour porpoise, however, there are still many unknowns and this field of research is relatively new. As for other pollutants and contaminants, micro-plastics are ingested through the food chain, and therefore accumulate in higher levels than are found in their prey species (Nelms et al., 2018). A study of the stomach contents of 47 harbour porpoise in the North Sea revealed that plastics were found in two of these individuals. As with other pollutants, a positive correlation has been noted with the level of micro-plastics found in harbour porpoise, and the number of harbour porpoise found to have died from disease. While this pattern has been noted, there are still too many unknowns in order to draw valid conclusions on the level of damage that micro-plastics are causing to the harbour porpoise population.

5.1.5.2 Summary of Pollution Impacts

It is currently unknown whether the effects of pollution on the harbour porpoise is increasing, decreasing or if there has been no change. It is also currently unknown which activity is causing the highest level of damage, with much of the impact on the harbour porpoise pollution being from historical sources (JNCC, 2019). The Conservation Plan for harbour porpoise within the North Sea note that the level of activity that contribute to contaminant discharge effects on the population is lower than that of the effects on the population associated with the construction industry (Reijnders et al., 2009).

As it is not possible to determine the source of the most damaging pollutant effects on harbour porpoise, and due to some of these pollution effects being historical in nature, as well as many unknowns on how much of an effect some of the pollution sources have on harbour porpoise (such as micro-plastics), a comparison of each activity is not possible for pollution.

5.1.6 Summary of relative impacts

A summary of how each of the activities/pressures considered with regard to impacts in the current situation to harbour porpoise are indicated below, relative to the relevant impact from offshore wind on each impact pathway is presented in Table 5-6.

Based on expert opinion following a review of the literature, it is concluded that bycatch due to gillnet fisheries is the activity/pressure/pathway that in the present day has the largest impact on harbour porpoise and is likely to be responsible for a substantially greater effect than impacts resulting from any of the other activities. The second largest effect on harbour porpoise is anticipated to be due to underwater noise impacts from shipping and oil and gas, largely due to the very high level of both activities that occur in the North Sea. While the impacts of climate change on harbour porpoise are noted to be unknown, there is the potential that these impacts may be considerable. All other activities are considered to have little to no effect on harbour porpoise at the wider North Sea level relative to fisheries, shipping, oil and gas and the potential impacts from climate change.

Table 5-6 Comparison of activities/pressures on harbour porpoise with equivalent pressure resulting from offshore wind development in the present-day scenario.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Underwater noise</th>
<th>Bycatch</th>
<th>Displacement</th>
<th>Collision Risk</th>
<th>Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Shipping</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>Considerably more than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>More than offshore wind</td>
<td>N/A</td>
<td>Similar to offshore wind</td>
<td>More than offshore wind</td>
<td>Comparison not possible</td>
</tr>
</tbody>
</table>
5.2  Kittiwake

5.2.1  Prey Availability

The primary prey species for breeding kittiwake may vary geographically. For example, birds breeding at colonies in the east of the UK rely extensively on sandeel (Furness and Tasker, 2000; Harris and Wanless, 1997; Lewis et al., 2001; Oro and Furness, 2002). Sandeel population declines in this region have been linked to kittiwake population declines, as explained in detail in Section 5.2.1.2. Kittiwakes breeding at two colonies in Ireland were found to rely on clupeids (Chivers et al., 2012), whilst whiting has been identified as the primary prey species at a colony the eastern North Sea (Markones et al., 2009).

Information regarding the non-breeding season diet of kittiwake (and of non-breeding birds during the breeding season) is sparser and will likely vary by location and time period within the non-breeding season. Sea butterflies in the Grand Banks/Labrador Sea area in winter and capelin in the Barents Sea in the pre-breeding season have both been identified as important food sources for kittiwake in different regions and time periods during the non-breeding season (Reiertsen et al., 2014). No further specific information was identified from the literature.

An overview of the level of impact on prey availability on kittiwake resulting from offshore wind is provided in Section 5.2.1.1, followed by a review of activities/pressures which contribute to kittiwake prey availability impacts in what is considered to be descending order of severity.

5.2.1.1  Offshore Wind

There is relatively limited scope for offshore wind to affect kittiwake prey availability. In terms of direct impacts, only a very small amount of seabed habitat is lost during the construction of offshore wind farms, meaning that the consequent permanent loss of prey species that may be associated with it (e.g. sandeel) is very small in magnitude. Furthermore, there is a possibility that positive prey availability effects could occur within operational offshore wind farms. This is partly due to the colonisation of structures such as monopiles, jacket foundations and scour protection by a range of organisms (Bergström et al., 2014; Langhamer, 2012; Linley et al., 2007), which in turn could lead to local increases in fish numbers. The fact that fishing is prohibited within many offshore wind farms could result in increased prey availability for
kittiwake. Whilst seabirds can suffer indirect prey availability impacts due to offshore wind farm development, kittiwake is not sensitive to this effect (Section 5.2.4).

Due to the fact that offshore wind farms are now relatively widespread in the marine environment, exposure of kittiwake to such impacts is considered moderate as there is considerable overlap between kittiwake habitat and offshore wind farm deployment, but sensitivity with respect to prey availability is estimated to be low based on the available evidence. Overall, the estimated impact level is considered to be low. Confidence in this prediction is high on the basis that several studies from operational wind farms appear to concur that effects are not large.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.2.1.2 Climate Change

A large body of evidence identifies climate change as a major driver of seabird population demographics worldwide, including kittiwake (Daunt and Mitchell, 2013; Frederiksen et al., 2004; MacDonald et al., 2015; Mitchell et al., 2020; Russell et al., 2015). A global study which included assessment of over 550 kittiwake colonies throughout the species breeding range concluded that climate change is the single most important factor in the major decline of kittiwake populations observed over recent decades, with populations being sensitive to the rate of warming rather than warming itself (Descamps et al., 2017). Similar conclusions regarding kittiwake and prey availability have been reached by a number of studies considering impacts on particular populations (Barrett et al., 2017; Frederiksen et al., 2004; Hátún et al., 2017; Reiertsen et al., 2014; Sandvik et al., 2005).

Much of the research on kittiwake prey availability has focused on sandeel, which is frequently (though not exclusively) the primary prey item for kittiwake. A range of mechanisms by which climate change can affect sandeel have been identified (Lindegren et al., 2018; MacDonald, 2015; MacDonald et al., 2019, 2018, 2015; Régnier et al., 2019; Sandvik et al., 2012, 2005; Wright et al., 2018). In general, as breeding season temperature have increased, kittiwake have struggled to find sufficient food for their chicks. This is because sandeels have been too few, too small, too lean, or have not been available at the right time (Brander et al., 2016). In geographical pockets where sandeel recruitment has been less affected by recent years of warmer temperatures (Frederiksen et al., 2005), and possibly in regions where sandeel is not the primary prey species, such effects have so far occurred to a lesser extent on kittiwake populations.

Recent research into potential future impacts of climate change on fish (ClimeFish, 2019) indicates that the magnitude of kittiwake prey availability impacts due to climate change in the future are likely to vary by location. It is possible that kittiwake may not have the ability to adapt its diet depending on the abundance of its primary prey species (Lewis et al., 2001), meaning that it is possible that for colonies where sandeel is the primary prey species, numbers of birds may continue to fall as birds fail to adapt to changes in the availability of their preferred prey.

In addition to indirect impacts of climate change on seabirds through prey availability, it is becoming increasingly apparent that seabirds, including kittiwake, are susceptible to substantial population-level impacts due to poor weather and extreme weather events (Daunt et al., 2017; Jenouvrier, 2013; Mitchell et al., 2020; Morley et al., 2016; Newell et al., 2015). These effects can manifest through chilling of eggs and killing of unfledged chicks during the breeding season and impairment of foraging (at all times of year). Generally speaking, climate models predict increased incidences of extreme weather in the future (Palmer et al., 2018), meaning that in the future, such effects on seabirds could increase in both frequency and magnitude.
Kittiwake have a high exposure to prey availability impacts caused by climate change as it affects birds constantly, though the sensitivity and level of impact appears to vary by region, which means that these predictions are based on areas where large numbers of birds are being impacted (i.e. a worst case prediction). It is concluded that in terms of prey availability, kittiwake is highly sensitive to these effects. The estimated impact level of climate change on kittiwake prey availability is therefore considered to be very high. Confidence in this prediction is also high based on high quality peer-reviewed evidence being available to justify it. Exposure and sensitivity are considered to be higher than equivalent effects for offshore wind.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>High</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>

### 5.2.1.3 Fisheries

Whilst the significance of climate change impacts exceeds any other factor contributing to kittiwake population declines on a global scale (Descamps et al., 2017), there is considerable geographical variation in the magnitude of the impact of climate change effects on kittiwakes. Whilst this can be at least partially explained by variability in food web impacts, another reason may be differences in other pressures on prey availability. Clear links between kittiwake breeding success and reduced sandeel availability due to fishing activities have been demonstrated (Carroll et al., 2017; Daunt et al., 2008; Frederiksen et al., 2004; Furness and Tasker, 2000; Greenstreet et al., 2010; Hayhow et al., 2017; Lindegren et al., 2018; Wright et al., 2018). It has been identified that three traits that make kittiwake particularly sensitive to sandeel depletion by fisheries activity are the species low ability to dive, lack of spare time in its daily budget, and its low ability to switch diet (Furness and Tasker, 2000). However, exactly why this occurs is unknown, as fishermen and kittiwakes target different age classes of sandeel.

At the Flamborough and Filey Coast SPA on the east coast of England, which supports around 45,000 breeding pairs of kittiwake (Natural England, 2018), it is estimated, using a range of demographic parameters for the North Sea (Horswill and Robinson, 2015), that the equivalent of up to 2,000 adults per year may be lost due to sandeel fishing activities. If this were also true at other colonies across Europe, numbers of kittiwake impacted through fisheries would be larger still. However, as impacts are likely to vary by region the true scale of this impact is not known.

It is known that seabirds, including kittiwake can obtain relatively large proportions of their diet from discards by fishing vessels (Bicknell et al., 2013; Foster et al., 2017; Votier et al., 2013). Cessation of this practice by the fishing industry due to the implementation of the Landing Obligation (Discard Ban), on commercial fishing vessels, which came into full effect in January 2019, may increase the pressure on kittiwake to obtain food from elsewhere. The potential magnitude of this impact on kittiwake at the population level is currently unknown.

It is concluded that kittiwake exposure to fisheries activities will vary enormously throughout the North Sea region, and also throughout the year. An exposure level of moderate is considered to be appropriate as there is substantial overlap between kittiwake habitat and fisheries activities. Sensitivity is estimated to be high given the well-established relationship recorded in the literature between sandeel fishing activity and kittiwake breeding success. The estimated impact level is therefore considered to be high.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
5.2.1.4 Sand and Gravel Extraction

Changes to the seabed that occur during sand and gravel extraction operations will affect fish species such as sandeel and therefore birds including kittiwake that utilise them as prey (Cook and Burton, 2010). Coarse and medium sand habitats preferred by sandeel may be replaced by the fine, silty sediments by sand and gravel extraction, which they avoid (Holland et al., 2005). Evidence from studies of shellfish dredging in the Netherlands also suggests that large populations of sandeel buried in the sediment can be destroyed as a result of dredging activities (Eleftheriou and Robertson, 1992). Habitat loss impacts resulting from sand and gravel extraction activities could last for a relatively long time after the activity has finished. Increases in turbidity and noise may result in a reduction in fish numbers in the vicinity of such activity (Cook and Burton, 2010), though such effects are all understood to be relatively localised and short-lived.

In the UK and the Netherlands, there is a statutory requirement to avoid marine sand and gravel dredging in areas where a significant impact on nursery or spawning grounds would result. Dredging is limited to areas of sea licensed by the Crown Estate in the UK (BMAPA and The Crown Estate, 2018) and Rijkswaterstaat in the Netherlands. This means that sand and gravel extraction is largely confined to particular areas, as opposed to occurring on larger spatial scales.

Many of these areas occur in far-shore locations, which minimise impacts on breeding kittiwake which will not forage at such great distances from their colonies. Whilst some licensed areas for marine sand and gravel extraction lie in areas where kittiwake would be expected to forage in some areas during the breeding season (i.e. the southern North Sea) and are large (approximately an equivalent area to that occupied by offshore wind farms), activities are often restricted to particular areas within them and are non-continuous. Where similar activities occur in ports or shipping channels, these are generally not considered optimal kittiwake foraging habitat.

**Exposure** is considered to be low for reasons described in the previous paragraph. **Sensitivity** however is estimated to be moderate (greater than for offshore wind) as there are several mechanisms by which kittiwake prey availability could be affected by marine sand and gravel extraction. As a result, the estimated **impact level** for sand and gravel extraction on kittiwake prey availability is low. These predictions are made with moderate confidence and are based partially on species-specific evidence and partially on expert opinion.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and gravel extraction</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.2.2 Bycatch

Like many species of seabird, kittiwake are potential victims of bycatch from fishing activities. None of the other pressures identified in Section 3 result in kittiwake mortality due to bycatch, including offshore wind (Table 3-2).

An annual estimate of 5,000 kittiwake fatalities in the north-western UK due to longline bycatch has previously been made (ICES, 2008), though it is unclear as to how this figure was calculated. However, it has also been noted that whilst often present in association with fishing vessels at sea, kittiwakes do not often show interest in attempting to remove bait from longline hooks, and in the rare cases where this was...
reported, were particularly adept at removing bait from longlines without being killed (Dunn and Steel, 2001). True impact levels are therefore uncertain and may vary by region.

Available literature suggests that kittiwake may not be susceptible to bycatch by other fishing techniques (e.g. gillnets). As kittiwakes are surface feeding birds (Cramp and Simmons, 1983), they will only be vulnerable to bycatch when trapped in gillnets near the surface of the water. A worldwide review of seabird mortality due to bycatch (Żydelis et al., 2013), whilst noting that kittiwake had previously been recorded as bycatch in a relatively small number of incidents, did not suggest that it was a species of high sensitivity. Three recent bycatch reports of monitored fishing vessels in the UK have not recorded a single kittiwake bycatch from 115 seabirds in three years (though two unidentified gulls were recorded) (Northridge et al., 2018, 2017, 2016). Whilst this monitoring effort covered only 3% of the UK fishing fleet, the boats in question are also responsible for 15-20% of fleet sea days and 50% of the catch. A smaller scale study in UK waters recorded no kittiwake bycatch on a range of pelagic trawling vessels (Pierce et al., 2002). Similar data collected from Icelandic gillnets recorded a single kittiwake bycatch victim over a four year period (Marine and Freshwater Research Institute, 2018). When scaled up to account for the unmonitored portion of the fishing fleet, a total of 4-5 kittiwakes per year was estimated.

It is concluded that kittiwake exposure to fisheries activities will vary enormously throughout the North Sea region, and also throughout the year. An exposure level of moderate is considered to be appropriate, because although there is temporal and spatial variability, there is clear overlap between kittiwake habitat and fisheries activities. The sensitivity of kittiwake to bycatch impacts is more uncertain given the conflicting evidence described above with respect to longlines, so is also assumed to be moderate, though confidence is low due to conflicting evidence identified in the literature. The estimated impact level is therefore moderate. There is a high certainty that fisheries is the only activity for which bycatch is relevant.

<table>
<thead>
<tr>
<th>Bycatch</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

5.2.3 Collision Risk

Two of the pressures identified in Section 3 could potentially result in substantial collision mortality for kittiwake (Table 3-2).

5.2.3.1 Offshore Wind

Kittiwake is vulnerable to collision with offshore wind turbines (Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). This is due to the distribution of birds relative to offshore wind farms, the fact that birds do not seem to be displaced in large numbers by their presence (Section 5.2.4), and the relatively high proportion (relative to some other seabird species) of birds flying at heights where they may pass through the rotor swept area when flying through offshore wind farms (Figure 5-5). Based on the best available data (Johnston et al., 2014a, 2014b), approximately 14% and 9% of birds fly at heights in excess of 20 m and 25 m from the surface of the sea respectively, which is often the approximate height at which the rotor swept area of many offshore wind turbines begins.
Approximately 3,700 kittiwake collisions per year are predicted for UK offshore wind farms currently operational in the North Sea (Macarthur Green and Royal HaskoningDHV, 2019). On the basis of current levels of offshore wind deployment in other European countries (GWEC, 2017), assuming that mortality levels and offshore wind farm abundance of kittiwake are similar in these countries (likely to be an overestimate based on kittiwake breeding distribution), it is possible that approximately double this number (7,400 birds) may be colliding with offshore wind turbines annually, though this would depend on the abundance of kittiwake at these wind farms. This is greater than a previously calculated estimate of approximately 3,200 birds (Leopold et al., 2014), though the same order of magnitude.

Kittiwake is considered to possess a moderate exposure and high sensitivity to collision risk with offshore wind farms based on the available literature, resulting in a high estimated impact level. Confidence is moderate on the basis that there is abundant literature on offshore wind farm impact assessment, but far less on validating the findings of such assessments and the collision risk modelling that underpins their predictions.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

### 5.2.3.2 Ocean Renewable Energy

Whilst the small scale at which ocean renewable energy has been deployed to date means that there is virtually no direct evidence available on this subject, so a degree of uncertainty surrounds potential impacts, kittiwake is not generally considered to be susceptible to the theoretical risk of underwater collision with wave, tidal and solar energy devices. This is because they are surface feeding birds, with dive depths not routinely exceeding 1m (Cramp and Simmons, 1983). Kittiwake will therefore not be likely to enter the collision risk depth of many ocean renewable energy devices, either routinely or in large numbers. Because of this, and due to the fact that ocean renewable energy has not yet been widely deployed at a commercial scale, exposure and sensitivity of kittiwake to collision with ocean renewable energy devices is considered to be low, meaning that the estimated impact level is very low. Whilst this...
prediction is partly based on known kittiwake behaviour, there is an element of it based on expert judgement. Confidence in the prediction of exposure is high, and sensitivity and impact level moderate.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.2.4 Disturbance and Displacement

Away from their breeding colonies, kittiwake are frequently insensitive to a range of visual and airborne noise disturbance stimuli from a range of sources, including many of the activities considered in Section 3. As there is a great deal of independently produced literature on the subject with broadly similar conclusions, confidence in kittiwake’s lack of susceptibility to this impact is high. However, there are likely to be exceptions, and spatial and temporal variation is possible. For example, it has been speculated that kittiwake are less susceptible to displacement during the chick-rearing period as they are inclined to engage in riskier behaviour in pursuit of successful provisioning compared to other times of year.

Kittiwake is not generally considered to be susceptible to displacement due to underwater noise impacts because they are surface feeding birds that do not spend large amounts of time underwater, with dive depths not routinely exceeding 1m (Cramp and Simmons, 1983).

5.2.4.1 Offshore Wind

A review of information from the post-construction monitoring of 20 offshore wind farms in Europe noted a mixture of weak avoidance or attraction, with no overall recognisable effect (Dierschke et al., 2016). Another study noted a mixture of displacement and no response to a range of wind farms, with an overall macro displacement effect of zero (Cook et al., 2018). Due to the fact that offshore wind farms are now relatively widespread and permanent in the marine environment, occupying relatively large areas of subtidal habitat (compared with other activities) and any displacement effects are either weak or inconsistent across multiple offshore wind farms, exposure of kittiwake to such impacts is considered moderate due to the overlap between kittiwake habitat and offshore wind farms, but sensitivity is generally low. The estimated impact level is therefore considered to be low. There is high confidence in the exposure and sensitivity estimates.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.2.4.2 Other Activities

There is a large amount of evidence demonstrating a lack of disturbance and displacement impacts on kittiwake due to shipping activity (Fliessbach et al., 2019; Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). Attraction towards vessels, particularly fishing as a food source has been widely observed in gulls, including kittiwake (Garthe and Hüppop, 1999; Tasker et al., 2000), indicating low sensitivity to the presence of vessels (and therefore to many of the activities listed in Section 3), despite a high exposure due to the fact that cumulatively, these are very widespread activities. The estimated impact level is therefore considered to be low. There is high confidence in this prediction due to the wide range of literature in agreement on this topic.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other activities</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
5.2.5 Pollution

There are different types of subtidal habitat pollution, all of which have to potential to affect seabirds, including kittiwake. Both lethal and sub-lethal effects can/may occur as a result of a variety of pollution events differing in spatial and temporal magnitude.

Acute isolated events such as petrochemical spills into subtidal habitats (a result of events such as oil or gas infrastructure blowouts or ship collision/grounding) can cause high levels of direct mortality at a relatively localised spatial scale, predominantly by the oiling of birds, and potentially the loss of prey and habitat, which can persist for months or years after a significant event. Whilst kittiwake can be harmed by such events, diving seabird species that spend more time on the water are more susceptible.

Less well understood in terms of ecological effects is chronic pollution as a result of offshore activities, with large numbers of smaller discharges reported each year (ACOPS, 2017). There are also numerous pollutants from onshore sources (e.g. polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs) and organophosphate esters which are likely to be contributing extensively to chronic pollution effects on the marine environment (Svendsen et al., 2018; Tartu et al., 2015).

In addition to acute and chronic chemical pollution, there has been a recent focus on the study of plastic pollution. This includes larger plastic debris (the potential effects of which are well known), as well as microplastics. The presence of plastics in marine environments is recognised as pervasive, and increasing (GESAMP, 2015; Ostle et al., 2019; Wilcox et al., 2015). In one study nearly 10% of unfledged kittiwakes were found to have ingested plastic (Acampora et al., 2017), though this was not correlated to any effect on the general health of these birds. As well as lethal effects of plastic ingestion, it is recognised that sub-lethal effects could also occur which may impact future population growth (Roman et al., 2019b); such effects are apparent in fish (Rochman et al., 2014) and may become apparent in higher predators in due course (Lavers et al., 2019). It has been suggested that surface feeding birds such as kittiwake may be more susceptible to plastic ingestion than species foraging in other parts of the water column (Roman et al., 2019a).

Whilst particularly large acute events may sometimes be attributable to oil and gas exploitation, it is not possible to attempt to assign sources to more chronic pollution events, which on the basis of the reviewed literature accounts for a much greater amount of pollution in the marine environment. As it is not possible to determine the source of the most damaging pollutant effects on kittiwake, and due to some of these pollution effects being historical in nature, as well as many unknowns on how much of an effect each pollution source has on birds, a comparison of each activity is not possible for pollution.

5.2.6 Summary of relative impacts

A summary of how each of the activities and pressures considered with regard to kittiwake in the above sections compare with the effect of offshore wind on each impact pathway is presented in Table 5-7. There is robust evidence available on many aspects of these pressures on kittiwake, but sometimes low agreement across the study area due to genuine differences with respect to primary prey species and the concentration of particular anthropogenic activities in particular areas.

Based on the available literature, it is concluded that prey availability effects on kittiwake (Section 5.2.1) are “very likely” (90-100% probability) to be due mainly to impacts of climate change (Section 5.2.1.2). These effects are considered “very likely” (90-100% probability) to be moderately exacerbated by prey
availability impacts due to fisheries activities (Section 5.2.1.3). It is acknowledged that due to fisheries activities being concentrated in particular areas, the level of impact will vary considerably geographically, and peak at times where particular fisheries are active. It is considered “very likely” (90-100% probability) that prey availability impacts due to offshore wind are relatively small (Section 5.2.1.1), so it is considered “virtually certain” (99-100% probability) that fisheries is a larger contributor to this impact compared to offshore wind. Due to a combination of the more numerous pathways of impact, but lower exposure for much of the wider North Sea, sand and gravel extraction (Section 5.2.1.4) is considered “likely” (66-100% probability) to have a similar effect on kittiwake prey availability in the wider North Sea area. The evidence presented in the literature review suggests that it is “very likely” (90-100% probability) that the other activities considered in Section 3 have a lower effect on kittiwake prey availability than offshore wind, and are therefore unlikely to contribute significantly to kittiwake prey availability impacts at the wider North Sea level compared to climate change and fisheries, though it is accepted that this situation may be different at a local level.

Like many species of seabird, kittiwake are potential victims of bycatch from fishing activities (Section 5.2.2). It is considered “virtually certain” (99-100% probability) that none of the other pressures identified in Section 3 result in kittiwake mortality due to bycatch, including offshore wind. As a result, bycatch impacts from fisheries are considered to be considerably larger than the equivalent impact of offshore wind (i.e. zero).

With regard to collision risk, ocean renewable energy and offshore wind were identified as activities that could potentially result in substantial numbers of collisions (Section 5.2.3). Due to the fact that kittiwake are not diving birds, their exposure to the moving parts of ocean renewable energy devices is expected to be much lower than their exposure to the rotor swept area of offshore wind turbines. Certainty of the exact level of these impacts is described as “likely” (66-100% probability), whilst the probability of the relative classification (i.e. offshore wind causes substantially more collisions than ocean renewable energy) is “virtually certain” (99-100% probability) due to known aspects of kittiwake foraging ecology.

For disturbance and displacement, it is considered that due to the relative insensitivity of kittiwake to this effect with regard to all activities/pressures (Section 5.2.4), there is no single activity that is clearly a dominant contributor to this impact at the wider North Sea level. However, offshore wind requires the permanent placement of very tall structures across large areas of subtidal habitat for an extended period of time (25 years, or more if repowering is considered), a practice that is widespread across many parts of the North Sea. On this basis, and based on the literature review, it is considered “about as likely as not” (33-66% probability) that offshore wind may have a slightly greater disturbance and displacement effect on kittiwake than all other activities described in Section 3 at the wider North Sea level, though it is accepted that the magnitude of these impacts will vary substantially by location.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Prey Availability</th>
<th>Bycatch</th>
<th>Collision Risk</th>
<th>Disturbance and Displacement</th>
<th>Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Similar to offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Ocean Renewable Energy</td>
<td>N/A</td>
<td>N/A</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
</tbody>
</table>
5.3 Guillemot

5.3.1 Prey Availability

5.3.1.1 Introduction

Guillemots possess deep diving capability for catching prey (Robbins, 2017), and are able to feed on both fish in the water column and benthic prey items. They are known to utilise a relatively wide range of prey items depending on region and time of year (Cramp, 1985). In the North Sea, a study of 26 colonies revealed sandeel to be the most common prey species, though historical comparisons indicate that the relative proportion of sandeel in the total diet has decreased (Anderson et al., 2014). In the Baltic Sea sprat is thought to be important based on a study of 64 dead birds (Lyngs and Durinck, 1998), with a Canadian study involving 107 dead birds identifying capelin as the primary prey species (Wilhelm et al., 2003). It seems that guillemot possess the capacity to make use of whatever prey items are abundant, and their diving capabilities provide additional flexibility to catch a range of prey. Less is known about the non-breeding diet of this species, though its relative flexibility with regard to diet is assumed to be as per the breeding season.

An overview of the level of impact on prey availability on guillemot resulting from offshore wind is provided in Section 5.3.1.2, followed by a review of activities which contribute to prey availability impacts in guillemot, in what is considered to be descending order of severity.

5.3.1.2 Offshore Wind

With respect to direct impacts of offshore wind farms on prey availability, a very small amount of seabed habitat is lost during the construction of offshore wind farms, meaning that the consequent loss of fish such as sandeel due to habitat loss is very small in magnitude. Furthermore, there is a possibility that positive prey availability effects could occur within operational offshore wind farms. This is partly due to the colonisation of structures such as monopiles, jacket foundations and scour protection by a range of organisms (Bergström et al., 2014; Langhamer, 2012; Linley et al., 2007), which could lead to local increases in fish numbers. The fact that fishing is prohibited within many offshore wind farms could result in increased prey availability. It is therefore considered that offshore wind farm development would have a relatively small effect on guillemot prey availability.
Offshore wind farms could affect guillemot prey availability indirectly through displacement of birds from potential foraging habitat, though the effect is not consistent (Degraer et al., 2016; Dierschke et al., 2016). This is discussed further in Section 5.3.4.

Due to the fact that offshore wind farms are now relatively widespread in the marine environment and overlap with guillemot habitat, exposure of guillemot to such impacts is considered moderate, whilst sensitivity is also judged to be moderate on the basis of inconsistent displacement of this species from offshore wind farms. Overall, the estimated impact level is considered to be moderate.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

5.3.1.3 Climate Change

A large body of evidence identifies climate change as a major driver of seabird population demographics worldwide, including guillemot (Daunt and Mitchell, 2013; MacDonald et al., 2015; Mitchell et al., 2020; Russell et al., 2015).

In guillemot breeding in the North Sea on the eastern UK coast, it has been shown that dietary changes have occurred in recent years, with birds feeding on an increasing proportion of sprat instead of sandeel (Anderson et al., 2014). This correlates with an increase in sprat abundance in this area (Alvarez-Fernandez et al., 2012). Whilst not definitively linked to climate change, this could be an example of a ‘bottom-up’ effect being driven by changes in climate. A change in diet composition in guillemots at Skomer Island in Wales has also been recorded, though again, no evidence exists to definitively link this alteration to climate change (Riordan and Birkhead, 2018). No evidence of a change in prey species by guillemot in other regions has been identified. However, it does appear that guillemot have the capacity for diversification of prey items.

Recent research into potential future impacts of climate change on fish (ClimeFish, 2019) indicates that the magnitude of guillemot prey availability impacts due to climate change are likely to vary by location. Whilst the apparent dietary flexibility of guillemot makes the species potentially more robust to such shifts in prey availability compared to species unable to display such prey flexibility, enforced shifts to lower quality prey would still be likely to result in effects on breeding success, bird survival, and population size to some degree.

In addition to indirect impacts of climate change on seabirds through prey availability, it is becoming increasingly apparent that seabirds, including guillemot, are susceptible to substantial population-level impacts due to poor weather and extreme weather events (Daunt et al., 2017; Jenouvrier, 2013; Mitchell et al., 2020; Morley et al., 2016; Newell et al., 2015). These effects can manifest through chilling of eggs and killing of unfledged chicks during the breeding season and impairment of foraging (at all times of year). Generally speaking, climate models predict increased incidences of extreme weather in the future (Palmer et al., 2018), meaning that such effects on seabirds could increase in both frequency and magnitude.

Guillemot, as with all seabirds, have a high exposure to prey availability impacts caused by climate change, though sensitivity to these impacts sensitivity is more difficult to estimate. The flexibility that guillemots possess with regard to water column usage (Mitchell et al., 2018b) and primary prey species (see literature cited above) might make them more robust to prey availability effects due to climate change compared to species such as kittiwake. As there is no evidence that population growth would not be larger in the absence of climate change effects, it is concluded that guillemot should be assumed to be sensitive
to climate change effects, though on the basis that they may not be as sensitive as kittiwake considering the population trend for that species (Section 5.2.1.2), high is considered to be an appropriate **impact level**. This is an assumed sensitivity of moderate confidence based on expert judgement and climate changes effects on other seabird species.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

### 5.3.1.4 Fisheries

Like all seabirds dependent on fish stocks, fisheries activities can impact guillemot due to reduced prey availability. However, guillemot does not appear to be as sensitive to effects during the breeding season as other species of seabird due to this pressure (Daunt *et al.*, 2008; Furness and Tasker, 2000), perhaps (though not certainly) due to its relative flexibility with regard to prey.

Guillemots are known to only occasionally exploit discards from fishing vessels (Bicknell *et al.*, 2013). Cessation of this practice by the fishing industry due to the implementation of the Landing Obligation (Discard Ban), on commercial fishing vessels, which came into full effect in January 2019, may increase the pressure on species including guillemot to obtain food from elsewhere, but only by a relatively small amount compared to species more reliant on discards. However, the potential magnitude of this impact on guillemot at the population level is currently unknown.

It is concluded that guillemot has a moderate **exposure** to fisheries activities as there is substantial overlap between guillemot habitat and fisheries activity, its **sensitivity** to this activity is also considered to be moderate based on the available literature. The resulting **impact level** is considered to be moderate. This assessment is made with moderate confidence.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

### 5.3.1.5 Sand and Gravel Extraction

Changes to the seabed that occur during dredging operations will affect fish species such as sandeel and therefore birds including guillemot (Cook and Burton, 2010). Coarse and medium sand habitats preferred by sandeel may be replaced by the fine, silty sediments by sand and gravel extraction, which they avoid (Holland *et al.*, 2005). Evidence from studies of shellfish dredging in the Netherlands also suggests that large populations of sandeel buried in the sediment can be destroyed as a result of dredging activities (Eleftheriou and Robertson, 1992). Habitat loss impacts resulting from sand and gravel extraction activities could last for a relatively long time after the activity has finished. Increases in turbidity and noise may result in a reduction in fish numbers in the vicinity of such activity (Cook and Burton, 2010), though such effects are all understood to be relatively localised and short-lived.

In the UK and the Netherlands, there is a statutory requirement to avoid marine sand and gravel dredging in areas where a significant impact on nursery or spawning grounds would result. Dredging is limited to areas of sea licensed by the Crown Estate in the UK (BMAPA and The Crown Estate, 2018) and Rijkswaterstaat in the Netherlands. This means that sand and gravel extraction is largely confined to particular areas, as opposed to occurring more widely.
The primary impact of sand and gravel extraction on guillemot prey availability is likely to be disturbance and displacement caused by the presence of vessels, which is discussed in Section 5.3.4.

Many licensed areas occur in far-shore locations, which minimise impacts on breeding guillemot which will not forage at such great distances from their colonies. However, whilst such areas may overlap with non-breeding season habitats, and are large (approximately an equivalent area to that occupied by offshore wind farms), activities are often restricted to particular areas within them and are non-continuous. Where similar activities occur in ports or shipping channels, these are generally not considered optimal guillemot foraging habitat. Exposure is therefore considered to be low. Sensitivity however is estimated to be moderate because there are several mechanisms identified by relevant literature by which guillemot prey availability could be affected by marine sand and gravel extraction. As a result, the estimated impact level for sand and gravel extraction on guillemot prey availability is low. These predictions are made with moderate confidence and are based partially on species-specific evidence and partially on expert opinion.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and gravel extraction</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

### 5.3.2 Bycatch

Like many species of seabird, guillemot are potential victims of bycatch from fishing activities, and their diving behaviour makes them particularly vulnerable to such impacts. None of the other pressures identified in Section 3 result in guillemot mortality due to bycatch, including offshore wind (Table 3-2).

Guillemot is among the most susceptible species to gillnet bycatch (Žydelis et al., 2013, 2009). Whilst it is beyond the scope of this document to accurately estimate numbers of annual guillemot deaths caused by bycatch in Europe, available research suggests that tens of thousands of birds is near certain, with upper estimates of beyond 100,000 possible, although it is noted that the highest estimates of bycatch referred to in the literature were generally historical, meaning that working practices may have improved, or the fisheries in question may no longer exist.

An annual estimate of many thousands of guillemot fatalities in the north-western UK due to longline bycatch across Europe has previously been made (ICES, 2008). However, many of the fishing areas which reported the largest guillemot bycatch are now closed (e.g. Norway). It has been noted that whilst occasionally present in association with fishing vessels at sea, guillemot do not show interest in attempting to remove bait from longline hooks (Dunn and Steel, 2001). True impact levels are therefore uncertain and are likely to vary by region and time of year.

It is considered that exposure of guillemot to this activity is moderate because although there is temporal and spatial variability, there is clear overlap between guillemot habitat and fisheries activities. The sensitivity of guillemot to bycatch impacts is high based on mortalities published in the literature. Overall, the estimated impact level of fisheries bycatch on guillemot is considered to be very high. This assessment is made with high confidence due to the depth of literature available, and their broad agreement on the magnitude of this issue.

<table>
<thead>
<tr>
<th>Bycatch</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>
5.3.3 Collision Risk

Two of the pressures identified in Section 3 are thought to result in potential collision mortality for guillemot (Table 3-2).

5.3.3.1 Offshore Wind

Guillemot is not considered especially vulnerable to collision with offshore wind turbines (Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). This is due largely to the low flight heights of this species (Figure 5-6). The fact that guillemots are sometimes displaced by offshore wind farms (Section 5.3.4) further reduces exposure to risks associated with flight through offshore wind farms. Based on the best available data (Johnston et al., 2014a, 2014b), approximately <0.5% of birds fly at heights in excess of 20m from the surface of the sea, which is often the approximate height at which the rotor swept area of many offshore wind turbines begins.

![Figure 5-6. Flight height distribution of guillemot from a large boat-based survey dataset (Johnston et al., 2014a, 2014b).](image)

The number of collisions predicted between offshore wind turbines and guillemots is thought to be negligible. Guillemot is considered to possess a low exposure and sensitivity to collision risk with offshore wind farms due to the fact that it is largely absent from the airspace which would render it vulnerable to collision with offshore wind turbines. The estimated impact level is also low. Confidence is high on the basis that there is high confidence regarding the flight height of guillemot below the rotor swept area of wind turbines.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.3.3.2 Ocean Renewable Energy

It is considered that guillemot will be susceptible to the (currently theoretical) risk of underwater collision with wave and tidal energy devices. Their deep diving abilities, along with their frequent habitat preference for high energy environments where wave and tidal development is more likely (Furness et al., 2013; Robbins, 2017) mean that for these developments, potential sensitivity of guillemot to collision mortality is considered to be higher than for collision with offshore wind turbines (i.e. moderate). The small scale at...
which ocean renewable energy has been deployed to date means that there is virtually no information available on this subject, and also means that current exposure is low. The current estimated impact level is low. Whilst this prediction is partly based on known guillemot behaviour, there is a large element of it based on expert judgement. Confidence in the prediction of exposure is high, and sensitivity and impact level low to moderate.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.3.4 Disturbance and Displacement

Guillemot can at times be relatively sensitive with respect to disturbance and displacement by a range of anthropogenic activities including many of those listed in Section 3 (Furness and Wade, 2012; Garthe and Hüppop, 2004). This is assumed to result mostly due to visual disturbance, though underwater and airborne noise could also influence behaviour based on the known hearing capabilities of this species (Mooney et al., 2019). Given birds can simply surface to escape underwater noise, it is currently not expected to be a substantial issue relative to marine mammals such as harbour porpoise (Section 5.1.4).

As with other seabirds species, the consequences of disturbance and displacement in terms of actual loss of birds to the population is poorly understood. It is possible that in terms of disturbance and displacement of birds at sea, those undergoing post-breeding moult (Cramp, 1985) may be the least able to respond to such impacts, which could possess greater population-level consequences.

5.3.4.1 Offshore Wind

A review of information from the post-construction monitoring of 20 offshore wind farms in Europe (Dierschke et al., 2016) noted the varied response of guillemot to offshore wind farms. Compared to pre-construction, guillemot abundance strongly decreased in some wind farms, but did not change or even increased in others. At some sites, birds were recorded only a few years after the beginning of the operational phase, perhaps in connection with a reef effect and thus an improved food supply, and/or habituation to the structures. Field observations suggested that birds avoid flying within some wind farms. Overall, the effect was described as weak avoidance of wind farms. On the basis that guillemot may be present in the North Sea for much of the year, and there is clearly overlap between their habitat and offshore wind farms, it is concluded that their exposure to such impacts is relatively high, with sensitivity considered to be moderate on the basis of proven displacement effects for this species (and the fact that it doesn’t seem to occur at all offshore wind farms). The estimated impact level is high. There is high confidence in the exposure and sensitivity estimates, though the population level consequences of displacement are not well understood.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

5.3.4.2 Shipping

There is a large body of evidence demonstrating disturbance and displacement impacts on guillemot due to shipping (Fliessbach et al., 2019; Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). It is generally understood that birds are of moderate sensitivity, with recent work suggesting an escape distance of up to several hundred metres (Fliessbach et al., 2019). As shipping is a common activity and birds are present in the North Sea throughout the year, exposure is high. The estimated impact level is considered to be moderate (i.e. lower than offshore wind) due to the temporary nature of
the disturbance (i.e. the fact that ships move through an area) and the fact that they do not result in
displacement from as large an area as an offshore wind farm. As there is extensive literature regarding the
effects of shipping on seabirds (including guillemot) there is high confidence in these exposure and
sensitivity estimates, though the population level consequences of displacement are not well understood.

Guillemot are assumed to be comparably sensitive to many of the other activities listed in Section 3 that
involve vessels (e.g. fisheries, oil and gas exploitation and sand and gravel extraction).

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

5.3.4.3 Ocean Renewable Energy

Due to a lack of commercial scale deployment, there is no data available for ocean renewable energy
development. Based on the nature of these developments compared to offshore wind (i.e. a reduced
amount of infrastructure above sea level relative to offshore wind), it is anticipated that disturbance and
displacement impacts will be reduced for sensitive bird species relative to offshore wind. At the present
time, exposure is considered to be low, and sensitivity is potentially moderate, resulting in a low
estimated impact level. There is a low certainty associated with the sensitivity estimate due to a lack of
commercial scale deployment (and consequently research) of these technologies to date.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.3.5 Pollution

There are different types of subtidal habitat pollution, all of which have the potential to affect seabirds,
including guillemot. Both lethal and sub-lethal effects can/may occur as a result of a variety of pollution
events differing in spatial and temporal magnitude.

Acute isolated events such as petrochemical spills into subtidal habitats (a result of events such as oil or
gas infrastructure blowouts or ship collision/grounding) can cause high levels of direct mortality at a
relatively localised spatial scale, predominantly by the oiling of birds, and potentially the loss of prey and
habitat, which can persist for months or years after a significant event. Guillemot, as a diving seabird
species that spends more time on the water than other species, is amongst the more susceptible species
to such incidents.

Less well understood in terms of ecological effects is chronic pollution as a result of offshore activities,
with large numbers of smaller discharges reported each year (ACOPS, 2017). There are also numerous
pollutants from onshore sources (e.g. polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers
(PBDEs), organochlorine pesticides (OCPs) and organophosphate esters which are likely to be
contributing extensively to chronic pollution effects on the marine environment (Svendsen et al., 2018;
Tartu et al., 2015).

In addition to acute and chronic chemical pollution, there has been a recent focus on the study of plastic
pollution. This includes larger plastic debris (the potential effects of which are well known), as well as
microplastics. The presence of plastics in marine environments is recognised as pervasive, and increasing
(GESAMP, 2015; Ostle et al., 2019; Wilcox et al., 2015). As well as lethal effects of plastic ingestion, it is
recognised that sub-lethal effects could also occur which may impact future population growth (Roman et
such effects are apparent in fish (Rochman et al., 2014) and will probably become apparent in higher predators in due course (Lavers et al., 2019).

Whilst particularly large acute events may sometimes be attributable to oil and gas exploitation, it is not possible to attempt to assign sources to more chronic pollution events, which on the basis of the reviewed literature accounts for a much greater amount of pollution in the marine environment.

As it is not possible to determine the source of the most damaging pollutant effects on guillemot, and due to some of these pollution effects being historical in nature, as well as many unknowns on how much of an effect each pollution source has on birds, a comparison of each activity is not possible for pollution.

5.3.6 Summary of relative impacts

A summary of how each of the activities/pressures considered with regard to guillemot in the above sections compare with offshore wind is presented in Table 5-8.

Based on the literature review, climate change (Section 5.3.1.3) is “virtually certain” (99-100% probability) to represent a greater influence on guillemot prey availability compared to offshore wind (Section 5.3.1.2). Whilst fisheries (Section 5.3.1.4) scored the same impact level as offshore wind, it is considered “likely” (66-100% probability) that fisheries has a bigger impact on guillemot prey availability. There is considerable difficulty in disentangling the combined effect on guillemot prey availability of fisheries and climate change. This is due to the prey flexibility of guillemot, as well as variation in the levels of impact of different activities/pressures across the wider North Sea area. On the basis of literature for other species (i.e. kittiwake (Section 5.2.1)) suggesting that climate change is the main driver behind prey availability reductions, and the fact that this impact pathway operates at a much wider spatial scale than fisheries, it is assumed that the same is true for guillemot. The prediction that climate change impacts on prey availability is a greater influence than fisheries is “very likely” (90-100% probability). It is acknowledged that due to fisheries activities being particularly concentrated in particular areas, the level of impact will vary geographically, and peak at times where particular fisheries are active. Due to a combination of the more numerous pathways of impact, but lower exposure for much of the wider North Sea, sand and gravel extraction (Section 5.3.1.5) is considered “likely” (66-100% probability) to have a similar effect on guillemot prey availability in the wider North Sea area as offshore wind. The evidence presented in the literature review suggests that it is “very likely” (90-100% probability) that the other activities considered in Section 3 have a lower effect on guillemot prey availability than offshore wind, and are therefore unlikely to contribute significantly to guillemot prey availability impacts at the wider North Sea level, though it is accepted that this situation may be different at a local level.

Like many species of seabird, guillemot are potential victims of bycatch from fishing activities (Section 5.3.2). It is considered “virtually certain” (99-100% probability) that none of the other pressures identified in Section 3 result in guillemot mortality due to bycatch, including offshore wind. As a result, bycatch impacts from fisheries are considered to be considerably larger than the equivalent impact of offshore wind (i.e. zero).

The impact of airborne collision mortality on guillemot due to offshore wind is considered to be negligible due to the known flight height distribution of this species (Section 5.3.3.1). At the present time, the same is true of ocean renewable energy, since deployment levels (and thus exposure) are very low, though it may be that guillemot are sensitive to underwater collision impacts in the future (Section5.3.3.2). Certainty of the exact level of these impacts is described as “likely” (66-100% probability), whilst the probability of the relative classification (i.e. similar levels of collision are expected from offshore wind and ocean renewable energy at the time of writing) is “very likely” (90-100% probability) due to known aspects of guillemot foraging ecology.
For disturbance and displacement, it is considered that guillemot are moderately sensitive to this effect with regard to all activities/pressures (Section 5.3.4), and there is no single activity that is clearly a dominant contributor to this impact at the wider North Sea level. However, offshore wind requires the permanent placement of very tall structures across large areas of subtidal habitat for an extended period of time (25 years, or more if repowering is considered), a practice that is widespread across many parts of the North Sea. On this basis, and based on the literature review, it is considered “about as likely as not” (33-66% probability) that offshore wind may have a greater disturbance and displacement effect on guillemot than all other activities described in Section 3, though it is accepted that the magnitude of these impacts will vary substantially by location.

Table 5-8. Comparison of activities/pressures on *guillemot* with pressures resulting from offshore wind development in the present-day scenario.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Prey Availability</th>
<th>Bycatch</th>
<th>Collision Risk</th>
<th>Disturbance and Displacement</th>
<th>Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not</td>
</tr>
<tr>
<td></td>
<td>than offshore wind</td>
<td></td>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore</td>
<td>Considerably</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td></td>
<td>wind</td>
<td>more than</td>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>offshore wind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand and Gravel</td>
<td>Similar to offshore</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td>Extraction</td>
<td>wind</td>
<td></td>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>Ocean Renewable</td>
<td></td>
<td></td>
<td>Similar to offshore</td>
<td>Less than offshore</td>
<td>Comparison not</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td>wind</td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>Military</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>possible</td>
</tr>
<tr>
<td>Shipping</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>Pollution Sources</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>possible</td>
</tr>
</tbody>
</table>

5.4 Lesser Black-backed Gull

5.4.1 Prey Availability

Lesser black-backed gull is opportunistic and flexible in its feeding habits, meaning that the list of species it consumes is extensive (Cramp and Simmons, 1983). Feeding habits vary not only geographically, but also between individuals from the same colony. This means there is considerable uncertainty associated with the relative contributions of different activities/pressures listed below on prey availability, as well as variation in the levels of impact of different activities/pressures across the wider North Sea area.
In the marine environment lesser black-backed gull is often a prolific scavenger of discards (Camphuysen, 2013). Data from one study suggested that non-discarded fish made up just 4% by biomass of all lesser black-backed gull fish prey (Camphuysen, 2011), though other studies have highlighted the importance of other marine food sources including swimming crabs (Luczak et al., 2012; Schwemmer and Garthe, 2005), clupeids, gadoids and sandeel (Bustnes, 2011).

It has also been shown that during the breeding season, lesser black-backed gull is able to exploit a variety of terrestrial foraging resources (Camphuysen, 2011; Garthe et al., 2016; Isaksson et al., 2016). Furthermore, growing numbers of lesser black-backed gulls appear to be breeding in urban environments (particularly in the UK), with some of these birds not utilising marine habitats for foraging (Rock, 2005; Spelt et al., 2019).

During the non-breeding season, the diet of lesser black-backed gulls is not characterised in the literature to the same extent as it is during the breeding season, but it is assumed that they retain the same opportunistic, flexible feeding characteristics. In some areas, discard availability has been closely linked to body condition and gull numbers during the non-breeding season (Hüppop and Wurm, 2000).

### 5.4.1 Offshore Wind

There is relatively limited scope for offshore wind to affect lesser black-backed gull prey availability. In terms of direct impacts, only a very small amount of seabed habitat is lost during the construction of offshore wind farms, meaning that the consequent permanent loss of prey species that may be associated with it (e.g. sandeel) is very small in magnitude. Such prey represents only a small fraction of the prey items available to this species (Section 5.4.1). There is a possibility that positive prey availability effects could occur within operational offshore wind farms for various reasons, but because lesser black-backed gull is so flexible with regard to prey, these relatively modest effects may not widely influence the behaviour or success of this species. Whilst seabirds can suffer indirect prey availability impacts due to offshore wind farm development because of disturbance and displacement, lesser black-backed gull is not sensitive to this effect (Section 5.4.4).

Due to the fact that offshore wind farms are now relatively widespread in the marine environment and they overlap considerably with lesser black-backed gull habitat, exposure of lesser black-backed gull to such impacts is considered to be moderate, but sensitivity is low based on the available evidence. The estimated impact level is considered to be low. Confidence in this prediction is high on the basis that several studies from operational wind farms appear to concur that effects are not large.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

### 5.4.1.2 Climate Change

A large body of evidence identifies climate change as a major driver of seabird population demographics worldwide, including lesser black-backed gull (Daunt et al., 2017; Daunt and Mitchell, 2013; MacDonald et al., 2015; Mitchell et al., 2020; Russell et al., 2015).

It has been suggested that a spatiotemporal coincidence of increased numbers of swimming crabs and an increase in the breeding lesser black-backed gull in the North Sea, and the correlation of these patterns to sea surface temperature may represent evidence of climate-driven changes in this species (Luczak et al., 2012). However, given the flexibility that lesser black-backed gull demonstrates with respect to food sources (Section 5.4.1), and the fact that the lesser black-backed gull population was growing prior to the
growth of the crab population (Shamoun-Baranes and Camphuysen, 2013), there may not be a causal link between crab abundance and lesser black-backed gull population growth.

There is apparently no link between the increased number of lesser black-backed gulls occurring in urban areas (Banks et al., 2007; Rock, 2005), reductions of populations in some coastal areas (which as much as anything may be due to bycatch declines) and climate change.

In addition to indirect impacts of climate change on seabirds through prey availability, it is becoming increasingly apparent that seabirds, including lesser black-backed gull, are susceptible to substantial population-level impacts due to poor weather and extreme weather events (Daunt et al., 2017; Jenouvrier, 2013; Mitchell et al., 2020; Morley et al., 2016; Newell et al., 2015). These effects can manifest through chilling of eggs and killing of unfledged chicks during the breeding season and impairment of foraging (at all times of year). Generally speaking, climate models predict increased incidences of extreme weather in the future (Palmer et al., 2018), meaning that in the future, such effects on seabirds could increase in both frequency and magnitude.

Whilst their flexibility in diet does not mean lesser black-backed gull is immune to the effects of climate change, it does make the species potentially more robust to change compared to species unable to display such prey flexibility. It is a surface feeding species, which have generally fared worse than other seabirds capable of using the entire water column (Mitchell et al., 2018b), though it has great habitat flexibility, which enables it to utilise terrestrial food sources as well as more traditional marine feeding grounds. However, enforced shifts to lower quality food would still be likely to result in effects on breeding success, bird survival, and population size.

Lesser black-backed gull have a high exposure to prey availability impacts caused by climate change, though the sensitivity is much more difficult to estimate. The apparent flexibility that this species possesses with regard to habitat and food source might make it more robust to prey availability effects due to climate change compared to other seabird species, and it could be argued that this is reflected in the continuing overall growth in the population of this species globally (though some populations, particularly at coastal locations are currently experiencing declines). As there is no evidence that population growth would not be larger in the absence of climate change effects, it is concluded that lesser black-backed gull should be assumed to be sensitive to climate change effects, though on the basis that they may not be as sensitive as kittiwake (Section 5.2.1.2), moderate is considered an appropriate sensitivity level, and high an appropriate estimated impact level. Confidence in this prediction is low on the basis that there is no species-specific evidence available. It is also considered that in reality, climate change effects probably vary substantially between different populations of this species.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

5.4.1.3 Fisheries

Whilst urban populations of lesser-black backed gull are largely unaffected by fisheries-related impacts due to their exploitation of alternative food sources, it is possible that coastal lesser black-backed gull colonies could be influenced by changes in fisheries activity given the extent to which some birds rely on discard (Camphuysen, 2011; Schwemmer and Garthe, 2005; Sotillo et al., 2014).

Whilst some birds have been recorded as being predominantly reliant on capturing prey and not discards (Bustnes, 2011), it is expected that lesser black-backed gulls are quite capable of adapting to local changes in fish availability due to the wide variety of prey they are capable of exploiting (Camphuysen,
It is speculated that this flexibility would help avoid population-level effects due to overfishing being avoided except in particularly extreme circumstances.

Regarding discard, there is evidence to suggest that individual gull populations can be strongly influenced by amounts of fish landed locally (Foster et al., 2017). However, whilst numbers of lesser black-backed gulls at some coastal locations have declined substantially in recent years, for example in the UK (Nager and O’Hanlon, 2016), the flexibility of this species with respect to prey means that other reasons for this decline, such as predation by species such as mink, disease, and culling are thought to be more responsible for these trends at the national level, though this is not certain.

It is concluded that lesser black-backed gulls breeding in coastal locations and utilising marine habitat for foraging will have an exposure to fisheries that will vary enormously throughout the North Sea region, and also throughout the year. An exposure level of moderate is considered to be appropriate as there is clearly overlap between lesser black-backed gull habitat and fisheries activities. Sensitivity is expected to be moderate given the relative prey flexibility of lesser black-backed gull based on the available literature. The estimated impact level is considered to be moderate. This assessment is made with moderate confidence.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

5.4.1.4 Sand and Gravel Extraction

Changes to the seabed that occur during sand and gravel extraction operations will affect fish species such as sandeel and therefore birds including lesser black-backed gull that utilise them as prey (Cook and Burton, 2010). Coarse and medium sand habitats preferred by sandeel may be replaced by the fine, silty sediments by sand and gravel extraction, which they avoid (Holland et al., 2005). Evidence from studies of shellfish dredging in the Netherlands also suggests that large populations of sandeel buried in the sediment can be destroyed as a result of dredging activities (Eleftheriou and Robertson, 1992). Habitat loss impacts resulting from sand and gravel extraction activities could last for a relatively long time after the activity has finished. Increases in turbidity and noise may result in a reduction in fish numbers in the vicinity of such activity (Cook and Burton, 2010), though such effects are all understood to be relatively localised and short-lived.

In the UK and the Netherlands, there is a statutory requirement to avoid marine sand and gravel dredging in areas where a significant impact on nursery or spawning grounds would result. Dredging is limited to areas of sea licensed by the Crown Estate in the UK (BMAPA and The Crown Estate, 2018) and Rijkswaterstaat in the Netherlands. This means that sand and gravel extraction is largely confined to particular areas, as opposed to occurring on larger spatial scales.

Many of these areas occur in far-shore locations, which minimise impacts on breeding lesser black-backed gull which will not forage at such great distances from their colonies. Whilst some licensed areas for marine sand and gravel extraction lie in areas where lesser black-backed gull would be expected to forage in some areas during the breeding season (i.e. the southern North Sea) and are large (approximately an equivalent area to that occupied by offshore wind farms), activities are often restricted to particular areas within them and are non-continuous. Where similar activities occur in ports or shipping channels, these are generally not considered optimal lesser black-backed gull foraging habitat. Exposure is therefore considered to be low, as is sensitivity. Whilst there are several mechanisms by which prey availability could be affected by marine sand and gravel extraction, the prey flexibility of lesser black-backed gull demonstrated by the literature review means it is likely to be able to find alternative sources of...
food relatively easily if required. The estimated impact level is considered to be low. These predictions are made with moderate confidence and are based partially on species-specific evidence and partially on expert opinion.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and gravel extraction</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.4.2 Bycatch

Like many species of seabird, lesser black-backed gull are potential victims of bycatch from fishing activities. None of the other pressures identified in Section 3 result in lesser black-backed gull mortality due to bycatch, including offshore wind (Table 3-2). Certainty of these impacts are thought to be relatively high; there is lots of literature on the subject available, with varying predictions. There is a high certainty that fisheries is the only activity for which bycatch is relevant.

An annual estimate of zero lesser black-backed gull fatalities across much of Europe due to longline bycatch has previously been made (ICES, 2008). However, it is hypothesised elsewhere that this species might be susceptible to bycatch, though there is no evidence available to support or refute this (Dunn and Steel, 2001). True impact levels are therefore uncertain and may vary by region.

Available literature suggests that lesser black-backed gull may not be susceptible to bycatch by other fishing techniques (e.g. gillnets). As lesser black-backed gulls are surface feeding birds (Cramp and Simmons, 1983), they will only be vulnerable to bycatch when trapped in gillnets near the surface of the water. A worldwide review of seabird mortality due to bycatch (Žydelis et al., 2013), whilst noting that gulls had previously been recorded as bycatch in a relatively small number of incidents, did not suggest that it was a species of high sensitivity. Three recent bycatch reports of monitored fishing vessels in the UK have not recorded a single lesser black-backed gull bycatch from 115 seabirds in three years (though two unidentified gulls were recorded) (Northridge et al., 2018, 2017, 2016). Whilst this monitoring effort covered only 3% of the UK fishing fleet, the boats in question are also responsible for 15-20% of fleet sea days and 50% of the catch. Similar data collected from Icelandic gillnets recorded no lesser black-backed gull bycatch victims over a four-year period (Marine and Freshwater Research Institute, 2018).

It is concluded that lesser black-backed gull exposure to this activity will vary enormously throughout the North Sea region, and also throughout the year. An exposure level of moderate is considered to be appropriate, because although there is temporal and spatial variability, there is clear overlap between lesser black-backed gull habitat and fisheries activities. The sensitivity of lesser black-backed gull to bycatch impacts is apparently low based on the available information. The estimated impact level is considered to be low. This assessment is made with high confidence due to the depth of literature available, and their broad agreement on the magnitude of this issue.

<table>
<thead>
<tr>
<th>Bycatch</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.4.3 Collision Risk

Two of the pressures identified in Section 3 are thought to have the potential to result in substantial collision mortality for lesser black-backed gull (Table 3-2).
5.4.3.1 Offshore Wind

Lesser black-backed gull is vulnerable to collision with offshore wind turbines (Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). This is due to the distribution of birds relative to offshore wind farms, the fact that birds are not displaced by their presence (Section 5.4.4), and the relatively high proportion (relative to some other seabird species) of birds flying at heights where they may pass through the rotor swept area when flying through offshore wind farms (Figure 5-7). Based on the best available data (Johnston et al., 2014a, 2014b), approximately 25% and 13% of birds fly at heights in excess of 20 m and 25 m from the surface of the sea respectively, which is often the approximate height at which the rotor swept area of many offshore wind turbines begins.

![Figure 5-7. Flight height distribution of lesser black-backed gull from a large boat-based survey dataset (Johnston et al., 2014a, 2014b).](image)

Approximately 500 lesser black-backed gull collisions per year are predicted for UK offshore wind farms currently operational in the North Sea (Macarthur Green and Royal HaskoningDHV, 2019). On the basis of current levels of offshore wind deployment in other European countries (GWEC, 2017), assuming that mortality levels and offshore wind farm abundance of lesser black-backed gull are the same in these countries, approximately double this total (approximately 1,000 birds) may be colliding with offshore wind turbines annually. This is less than a previously calculated estimate of approximately 3,700 birds (Leopold et al., 2014), though the same order of magnitude.

Recent work on lesser black-backed gull behaviour in operational offshore wind farms indicates highest collision vulnerability at sites within foraging range of breeding colonies, and also at migration bottlenecks and in proximity to wintering sites (Thaxter et al., 2019). However, high levels of avoidance of turbine rotor swept areas within offshore wind farms suggest that the behaviour of this species has possible adapted within offshore wind farms to reduce the probability of collision (Thaxter et al., 2018).

Lesser black-backed gull is considered to possess a moderate exposure and sensitivity to collision risk with offshore wind farms. Equally, the estimated impact level is also considered to be very high.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

5.4.3.2 Ocean Renewable Energy

Whilst the small scale at which ocean renewable energy has been deployed to date means that there is virtually no direct evidence available on this subject, so a degree of uncertainty surrounds potential impacts, lesser black-backed gull is not generally considered to be susceptible to the theoretical risk of underwater collision with wave and tidal devices. This is because they are surface feeding birds, with dive depths not routinely exceeding 1m (Cramp and Simmons, 1983). They will therefore not enter the collision risk depth of many ocean renewable energy devices. Because of this, and due to the fact that ocean renewable energy has not yet been widely deployed at a commercial scale, exposure and sensitivity of lesser black-backed gull to collision with ocean renewable energy devices is considered to be low, as is the estimated impact level.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.4.4 Disturbance and Displacement

It is generally accepted that away from their breeding colonies, lesser black-backed gull are relatively insensitive to a range of visual and airborne noise disturbance stimuli from a range of sources, including many of the activities considered in Section 3.

Lesser black-backed gull is not generally considered to be susceptible to underwater noise impacts because they are surface feeding birds not spending large amounts of time underwater, with dive depths not routinely exceeding 1m (Cramp and Simmons, 1983).

5.4.4.1 Offshore Wind

A review of information from the post-construction monitoring of 20 offshore wind farms in Europe noted an overall weak attraction effect (Dierschke et al., 2016). This was noted to be due to gulls utilising offshore wind farm structures for roosting, though it was also found that birds were often drawn away from offshore wind farms by the presence of nearby fishing vessels. Regular use of offshore wind farms is also reported in more recent tracking studies (Thaxter et al., 2019, 2018). That being said, a range of effects, including displacement, were reported by another study (Cook et al., 2018). Due to the fact that offshore wind farms are now relatively widespread in the marine environment and overlap with lesser black-backed gull habitat, exposure of lesser black-backed gulls to such impacts is considered to be moderate, but sensitivity is low based on the literature examined. The estimated impact level is low. Confidence in this prediction is moderate on the basis that there is abundant literature on offshore wind farm impact assessment, but far less on validating the findings of such assessments and the collision risk modelling that underpins their predictions.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.4.4.2 Other Activities

There is a large amount of evidence demonstrating a lack of disturbance and displacement impacts on lesser black-backed gull due to shipping activity (Fliessbach et al., 2019; Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). Attraction towards vessels, particularly fishing as a food source has been widely observed in gulls, including lesser black-backed gull (Garthe and Hüppop, 1999;
Tasker et al., 2000), indicating low sensitivity to the presence of vessels (and therefore to many of the activities listed in Section 3), despite a high exposure due to it being a common activity. The estimated impact level is therefore considered to be low. There is high confidence in this prediction due to the wide range of literature in agreement on this topic.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other activities</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.4.5 Pollution

There are different types of subtidal habitat pollution, all of which have to potential to affect seabirds, including lesser black-backed gull. Both lethal and sub-lethal effects can/may occur as a result of a variety of pollution events differing in spatial and temporal magnitude.

Acute isolated events such as petrochemical spills into subtidal habitats (a result of events such as oil or gas infrastructure blowouts or ship collision/grounding) can cause high levels of direct mortality at a relatively localised spatial scale, predominantly by the oiling of birds, and potentially the loss of prey and habitat, which can persist for months or years after a significant event. Whilst lesser black-backed gull can be harmed by such events, diving seabird species that spend more time on the water are more susceptible.

Less well understood in terms of ecological effects is chronic pollution as a result of offshore activities, with large numbers of smaller discharges reported each year (ACOPS, 2017). There are also numerous pollutants from onshore sources (e.g. polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs) and organophosphate esters which are likely to be contributing extensively to chronic pollution effects on the marine environment (Svendsen et al., 2018; Tartu et al., 2015).

In addition to acute and chronic chemical pollution, there has been a recent focus on the study of plastic pollution. This includes larger plastic debris (the potential effects of which are well known), as well as microplastics. The presence of plastics in marine environments is recognised as pervasive, and increasing (GESAMP, 2015; Ostle et al., 2019; Wilcox et al., 2015). As well as lethal effects of plastic ingestion, it is recognised that sub-lethal effects could also occur which may impact future population growth (Roman et al., 2019b); such effects are apparent in fish (Rochman et al., 2014) and may become apparent in higher predators in due course (Lavers et al., 2019). It has been suggested that surface feeding birds such as lesser black-backed gull may be more susceptible to plastic ingestion than species foraging in other parts of the water column (Roman et al., 2019a).

Whilst particularly large acute events may sometimes be attributable to oil and gas exploitation, it is not possible to attempt to assign sources to more chronic pollution events, which on the basis of the reviewed literature seem to account for a much greater amount of pollution in the marine environment.

As it is not possible to determine the source of the most damaging pollutant effects on lesser black-backed gull, and due to some of these pollution effects being historical in nature, as well as many unknowns on how much of an effect each pollution source has on birds, a comparison of each activity is not possible for pollution.
5.4.6 Summary of relative impacts

A summary of how each of the activities/pressures considered with regard to lesser black-backed gull in the above sections compare with offshore wind is presented in Table 5-9. There is robust evidence available on many aspects of these pressures on lesser black-backed gull, but sometimes low agreement across the study area due to genuine differences with respect to primary prey species and the concentration of particular anthropogenic activities in particular areas.

Based on the literature review, it is “virtually certain” (99-100% probability) that both fisheries (Section 5.4.1.3) and climate change (Section 5.4.1.2) represent greater influences on lesser black-backed gull prey availability than offshore wind. There is considerable difficulty in disentangling the combined effect on lesser black-backed gull prey availability of fisheries and climate change. This is due to the prey flexibility of lesser black-backed gull, as well as variation in the levels of impact of different activities/pressures across the wider North Sea area. On the basis of literature for other species (i.e. kittiwake (Section 5.2.1)) suggesting that climate change is the main driver behind prey availability reductions and the fact that climate change operates at a much large spatial scale, it is assumed that the same is true for lesser black-backed gull. The prediction that climate change impacts on prey availability is a greater influence than fisheries is “likely” (66-100% probability). It is acknowledged that due to fisheries activities being particularly concentrated in particular areas, the level of impact will vary geographically, and possibly peak at times where particular fisheries are active. Due to a combination of the more numerous pathways of impact, but lower exposure for much of the wider North Sea, sand and gravel extraction (Section 5.4.1.4) is considered “likely” (66-100% probability) to have a similar effect on lesser black-backed gull prey availability as offshore wind in the wider North Sea area. The evidence presented in the literature review suggests it is “very likely” (90-100% probability) that the other activities considered in Section 3 have a lower effect on lesser black-backed gull prey availability than offshore wind, and are therefore unlikely to contribute significantly to black-backed gull prey availability impacts at the wider North Sea level compared to climate change and fisheries, though it is accepted that this situation may be different at a local level.

Like many species of seabird, lesser black-backed gull are potential victims of bycatch from fishing activities (Section 5.4.2). It is considered “virtually certain” (99-100% probability) that none of the other pressures identified in Section 3 result in lesser black-backed gull mortality due to bycatch, including offshore wind. As a result, bycatch impacts from fisheries are considered to be considerably larger than the equivalent impact of offshore wind (i.e. zero).

With regard to collision risk, only ocean renewable energy and offshore wind were identified as activities that could potentially result in substantial numbers of collisions (Section 5.4.3). Due to the fact that lesser black-backed gull are not diving birds, their exposure to the moving parts of ocean renewable energy devices is expected to be much lower than their exposure to the rotor swept area of offshore wind turbines. Relatively speaking, the impact of ocean renewable energy collision risk is predicted to be considerably lower than offshore wind. Certainty of the exact level of these impacts is described as “likely” (66-100% probability), whilst the probability of the relative classification (i.e. offshore wind causes substantially more collisions than ocean renewable energy) is “virtually certain” (99-100% probability) due to known aspects of lesser black-backed gull foraging ecology.

For disturbance and displacement, it is considered that due to the relative insensitivity of lesser black-backed gull to this effect with regard to all activities/pressures (Section 5.4.4), there is no single activity that is clearly a dominant contributor to this impact at the wider North Sea level. However, offshore wind requires the permanent placement of very tall structures across large areas of subtidal habitat for an extended period of time (25 years, or more if repowering is considered), a practice that is widespread across many parts of the North Sea. On this basis, and based on the literature review, it is considered
“about as likely as not” (33-66% probability) that offshore wind may have a slightly greater disturbance and displacement effect on lesser black-backed gull than all other activities described in Section 3 at the wider North Sea level, though it is accepted that the magnitude of these impacts will vary substantially by location.

Table 5-9. Comparison of activities/pressures on lesser black-backed gull with pressures resulting from offshore wind development in the present-day scenario.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Prey Availability</th>
<th>Bycatch</th>
<th>Collision Risk</th>
<th>Disturbance and Displacement</th>
<th>Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Similar to offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Ocean Renewable Energy</td>
<td>N/A</td>
<td>N/A</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Military</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Shipping</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Pollution Sources</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
</tbody>
</table>

5.5 Red-throated Diver

5.5.1 Prey Availability

5.5.1.1 Introduction

Red-throated divers possess diving capabilities for catching prey (Robbins, 2017), and are thought to be capable of feeding on fish associated with the water column and seabed. It is hypothesised that due to their reliance on nearshore, shallow, sandy marine habitat, much feeding occurs in association with the seabed (Dierschke et al., 2017).

A study carried out on 34 birds in the German Bight (Kleinschmidt et al., 2019, 2016) found that red-throated divers in this area were opportunistic feeders, with broad prey spectrum of 19 fish taxa from 13 families dominated by five groups: clupeids, mackerel, gadoids, flatfish and sand lances. It was concluded that benthic prey items were unimportant to the sampled birds. Similar conclusions were reached by a study focused on a small number of birds from the Pomeranian Bight (Guse et al., 2009). A long term study carried out on bird carcasses found in the Netherlands suggested that location, season and health status are key influences on the dietary composition of red-throated divers, indicating that healthier birds...
may favour a mixture of fatty clupeids and larger gadoids, whilst sick or oiled birds may relax their preferences (Leopold, 2016). The apparent opportunistic feeding nature of this species means that the relative importance of particular species in the diet of red-throated diver may vary by geographical area and may also vary temporally during the non-breeding season.

An overview of the level of impact on prey availability on red-throated diver resulting from offshore wind is provided in Section 5.5.1.2, followed by a review of activities which contribute to prey availability impacts in red-throated diver, in what is considered to be descending order of severity.

### 5.5.1.2 Offshore Wind

With respect to direct impacts of offshore wind farms on prey availability, a very small amount of seabed habitat is lost during the construction of offshore wind farms, meaning that the consequent loss of fish such as sandeel due to habitat loss is very small in magnitude. Furthermore, there is a possibility that positive prey availability effects could occur within operational offshore wind farms. This is partly due to the colonisation of structures such as monopiles, jacket foundations and scour protection by a range of organisms (Bergström et al., 2014; Langhamer, 2012; Linley et al., 2007), which could lead to local increases in fish numbers. The fact that fishing is prohibited within many offshore wind farms could result in increased prey availability for birds not displaced by wind farm development.

However, offshore wind farms affect red-throated diver prey availability indirectly through displacement of birds from potential foraging habitat (Degraer et al., 2016; Dierschke et al., 2016), assuming that prey is present where they are constructed. This is discussed further in Section 5.5.4.

On balance, it is therefore considered that offshore wind farm development could potentially have a relatively substantial effect on red-throated diver prey availability. Offshore wind farms are now relatively widespread in the marine environment and there is some overlap with non-breeding red-throated diver habitat, so exposure of red-throated diver to such impacts is considered to be moderate. Sensitivity is considered high, as near total displacement of this species may occur following offshore wind farm construction. Overall, the estimated impact level is considered to be high. Confidence in this assessment is rated as being moderate.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

### 5.5.1.3 Climate Change

A large body of evidence identifies climate change as a major driver of seabird population demographics worldwide (Daunt et al., 2017; Daunt and Mitchell, 2013; MacDonald et al., 2015; Mitchell et al., 2020). No direct evidence of non-breeding red-throated diver behavioural change as a result of climate change has been identified. As a species capable of using the entire water column to feed (albeit only in relatively shallow areas) with a relatively wide range of possible prey items, it may be that red-throated divers may be somewhat buffered against some climate change-related effects relative to surface feeding seabirds, which based on information collected in the UK, are experiencing larger amounts of reductions in abundance (Mitchell et al., 2018b, 2018a). However, given this species is largely distributed across shallow waters in coastal locations (unlike many seabirds), this may equally not be the case and is considered to be uncertain.

In the UK, it is predicted that climate change may have a positive effect on the population of non-breeding red-throated diver (Burton et al., 2020). It is presumed however, that at the North Sea level, this is unlikely
to be consistently the case across the entire region. In addition, any reduction in breeding success that could occur as a result of climate change will have a knock-on effect on the non-breeding population.

Red-throated diver have a high **exposure** to prey availability impacts caused by climate change, though the **sensitivity** is more difficult to estimate due to a lack of evidence on the subject. On the basis that they may not be as sensitive as kittiwake based on recent population changes (Section 5.2.1.2), a moderate sensitivity and high **impact level** is estimated, though confidence in this assessment is low, as it is essentially based on published climate change effects for other seabird species. Given that this species has a substantially different ecology to “true” seabirds it might be that effects are somewhat different (though the paucity of data means it is not possible to further understand this).

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

### 5.5.1.4 Fisheries

Like all seabirds dependent on fish stocks, fisheries activities can impact red-throated diver due to reduced prey availability. However, there has been limited research undertaken with respect to this particular species.

Red-throated diver is not known to regularly exploit discards, meaning the implementation of the discard ban is not likely to impact this species.

As very little species-specific data were available, the prediction of sensitivity and impact level for red-throated diver is considered to be particularly uncertain. Based largely on expert opinion, red-throated diver is anticipated to have a moderate **exposure** and **sensitivity** to fisheries activities with respect to prey availability, given the overlap between red-throated diver habitat and fisheries activities. The resulting impact level is considered to be **moderate**. This assessment is made with low confidence.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

### 5.5.1.5 Sand and Gravel Extraction

Changes to the seabed that occur during dredging operations will affect fish species such as sandeel and therefore birds including red-throated diver (Cook and Burton, 2010). Coarse and medium sand habitats preferred by sandeel may be replaced by the fine, silty sediments by sand and gravel extraction, which they avoid (Holland *et al.*, 2005). Evidence from studies of shellfish dredging in the Netherlands also suggests that large populations of sandeel buried in the sediment can be destroyed as a result of dredging activities (Eleftheriou and Robertson, 1992). Habitat loss impacts resulting from sand and gravel extraction activities could last for a relatively long time after the activity has finished. Increases in turbidity and noise may result in a reduction in fish numbers in the vicinity of such activity (Cook and Burton, 2010), though such effects are all understood to be relatively localised and short-lived.

In the UK and the Netherlands, there is a statutory requirement to avoid marine sand and gravel dredging in areas where a significant impact on nursery or spawning grounds would result. Dredging is limited to areas of sea licensed by the Crown Estate in the UK (BMAPA and The Crown Estate, 2018) and Rijkswaterstaat in the Netherlands. This means that sand and gravel extraction is largely confined to particular areas, as opposed to occurring more widely.
The primary impact of sand and gravel extraction on red-throated diver prey availability is likely to be disturbance and displacement caused by the presence of vessels, which is discussed in Section 5.5.4. Many licensed areas occur in far-shore locations, which minimise impacts on red-throated diver, which is largely confined shallow waters in coastal locations. Where similar activities occur in ports or shipping channels, it is likely that red-throated diver will not be present due to displacement (Section 5.5.4). Exposure is considered to be low. Sensitivity is also estimated to be low. As a result, the estimated impact level for sand and gravel extraction on red-throated diver prey availability is low. These predictions are made with moderate confidence and are based partially on species-specific evidence and partially on expert opinion.

<table>
<thead>
<tr>
<th>Prey availability</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and gravel extraction</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.5.2 Bycatch

Like many species of seabird, red-throated diver are potential victims of bycatch from fishing activities, and their diving behaviour makes them particularly vulnerable to such impacts. Except for potentially aquaculture (though there is not yet any evidence of it occurring as the industry is relatively small), none of the other pressures identified in Section 3 result in red-throated diver mortality due to bycatch, including offshore wind (Table 3-2).

Red-throated diver is particularly susceptible to gillnet bycatch (Žydelis et al., 2013, 2009). Whilst it seems to be recorded as a victim of gillnet bycatch in many areas of Europe, mortality is much higher in the USA, and it is not considered to be “significantly affected” in Europe by bycatch according to relevant literature (Žydelis et al., 2013).

It is likely that due to their aversion to anthropogenic activity and sensitivity to displacement by vessel traffic (Section 5.5.4), red-throated diver are unlikely to regularly interact with fishing gear attached to a boat (except in the case of longlines), though issues caused by other types of fishing gear are considered likely.

As non-breeding red-throated diver largely inhabit shallow, coastal waters, only coastal fisheries activities have the potential to cause bycatch impacts on this species. Exposure of red-throated diver to this activity is assumed to be moderate. The sensitivity of red-throated diver to bycatch impacts is moderate based on European mortalities published in the literature. Overall, the estimated impact level of fisheries bycatch on red-throated diver is moderate. This assessment is made with moderate confidence due to the species-specific literature on sensitivity available. No prediction is made for bycatch impacts due to aquaculture due to a lack of information.

<table>
<thead>
<tr>
<th>Bycatch</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
5.5.3 Collision Risk

One of the pressures identified in Section 3 (ocean renewable energy) is thought to result in potential collision mortality for red-throated diver (Table 3-2).

5.5.3.1 Offshore Wind

Red-throated diver is not considered vulnerable to collision with offshore wind turbines (Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). This is due largely to the near total displacement of red-throated divers from offshore wind farms (Section 5.5.4).

The number of collisions predicted between offshore wind turbines and red-throated diver is thought to be negligible. Red-throated diver is considered to possess a low exposure and sensitivity to collision risk with offshore wind farms due to the fact that it is largely absent from the airspace which would render it vulnerable to collision with offshore wind turbines. The estimated impact level is also low. The certainty of this prediction is high as there is a great deal of evidence of displacement of this species from offshore wind farms available which share similar conclusions, indicating that collision of this species with wind turbines is highly unlikely (Section 5.5.4.1).

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.5.3.2 Ocean Renewable Energy

It is considered likely that red-throated diver will be susceptible to the theoretical risk of underwater collision with wave and tidal energy devices. Their diving abilities, along with their frequent preference for shallow, coastal environments where wave and tidal development is more likely (Furness et al., 2013; Robbins, 2017) mean that for these developments, potential sensitivity of red-throated diver to collision mortality is considered to be moderate; higher than for collision with offshore wind turbines. The small scale at which ocean renewable energy has been deployed to date means that there is virtually no information available on this subject, and also means that current exposure is low. The current estimated impact level is low. Whilst this prediction is partly based on known red-throated diver behaviour, there is a large element of it based on expert judgement. Confidence in the prediction of exposure is high, and sensitivity and impact level low to moderate.

<table>
<thead>
<tr>
<th>Collision risk</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.5.4 Disturbance and Displacement

Red-throated diver is known to be extremely sensitive with respect to disturbance and displacement by a range of anthropogenic activities including many of those listed in Section 3 (Furness and Wade, 2012; Garthe and Hüppop, 2004). This is assumed to result mostly due to visual disturbance. A range of species-specific studies have recorded avoidance of shipping areas and offshore wind farms across Europe, with such behaviour possible at distances of up to 20km from the relevant activity, though this distance can be less (Dierschke et al., 2017; McGovern et al., 2016; Mendel et al., 2019; Nehls et al., 2018). As with other seabird species, the consequences of disturbance and displacement in terms of actual loss of birds to the population is poorly understood.
5.5.4.1 Offshore Wind

A review of information from the post-construction monitoring of 20 offshore wind farms in Europe (Dierschke et al., 2016) classified red-throated diver as “strongly or (nearly) completely avoiding offshore wind farms”. Studies which have focused on particular sites have also examined displacement from buffer zones around wind farms, with variable results. This has included displacement evidence out to 16.5km from wind farms (with the strongest effects within 10km) (Mendel et al., 2019), 9km during construction, with reduced displacement in the first year of operation (McGovern et al., 2016), to less than 1km during operation (Percival, 2014). Whilst there are unknowns regarding the extent of wind farm displacement, particularly in long term deployments, and the population-level consequences of such disturbance, it is concluded that exposure of red-throated diver to such impacts is moderate given the overlap between offshore wind farms and non-breeding red-throated diver habitat, with sensitivity considered to be high based on a range of literature sources. The estimated impact level is also considered to be high. There is high confidence in the exposure and sensitivity estimates, though as stated above, the population level consequences of displacement are not well understood.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

5.5.4.2 Shipping

There is a large body of evidence demonstrating disturbance and displacement impacts on red-throated diver due to shipping (Fliessbach et al., 2019; Furness et al., 2013; Furness and Wade, 2012; Garthe and Hüppop, 2004). It is generally understood that birds are of high sensitivity with respect to other seabirds, with recent work suggesting an escape distance of up to 750-1000m, and over 90% of bird eliciting some sort of response to the presence of ships (Fliessbach et al., 2019). As shipping is a common activity, exposure is high; the estimated impact level is judged to be high. Red-throated diver are assumed to be comparably sensitive to many of the other activities listed in Section 3 that involve vessels (e.g. fisheries, oil and gas exploitation and sand and gravel extraction). As there is extensive literature regarding the effects of shipping on seabirds (included red-throated diver) there is high confidence in these exposure and sensitivity estimates, though the population level consequences of displacement are not well understood.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

5.5.4.3 Ocean Renewable Energy

Due to a lack of commercial scale deployment, there is no data available for displacement of red-throated diver by ocean renewable energy development. Based on the nature of these developments compared to offshore wind (i.e. a reduced amount of infrastructure above sea level relative to offshore wind), it is anticipated that whilst there may be disturbance and displacement impacts, they could be reduced for sensitive bird species relative to offshore wind. At the present time, exposure is considered to be low, and sensitivity is potentially moderate, resulting in a low estimated impact level. There is a low certainty associated with the sensitivity estimate due to a lack of commercial scale deployment (and consequently research) of these technologies to date.

<table>
<thead>
<tr>
<th>Disturbance and displacement</th>
<th>Exposure</th>
<th>Sensitivity</th>
<th>Impact level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
</tbody>
</table>
5.5.5 Pollution

There are different types of subtidal habitat pollution, all of which have the potential to affect seabirds, including red-throated diver. Both lethal and sub-lethal effects can/may occur as a result of a variety of pollution events differing in spatial and temporal magnitude.

Acute isolated events such as petrochemical spills into subtidal habitats (a result of events such as oil or gas infrastructure blowouts or ship collision/grounding) can cause high levels of direct mortality at a relatively localised spatial scale, predominantly by the oiling of birds, and potentially the loss of prey and habitat, which can persist for months or years after a significant event. Red-throated diver, as a diving seabird species that spends more time on the water than other species, is amongst the more susceptible species to such incidents.

Less well understood in terms of ecological effects is chronic pollution as a result of offshore activities, with large numbers of smaller discharges reported each year (ACOPS, 2017). There are also numerous pollutants from onshore sources (e.g. polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs) and organophosphate esters which are likely to be contributing extensively to chronic pollution effects on the marine environment (Svendsen et al., 2018; Tartu et al., 2015).

In addition to acute and chronic chemical pollution, there has been a recent focus on the study of plastic pollution. This includes larger plastic debris (the potential effects of which are well known), as well as microplastics. The presence of plastics in marine environments is recognised as pervasive, and increasing (GESAMP, 2015; Ostle et al., 2019; Wilcox et al., 2015). As well as lethal effects of plastic ingestion, it is recognised that sub-lethal effects could also occur which may impact future population growth (Roman et al., 2019b); such effects are apparent in fish (Rochman et al., 2014) and will probably become apparent in higher predators in due course (Lavers et al., 2019).

Whilst particularly large acute events may sometimes be attributable to oil and gas exploitation, it is not possible to attempt to assign sources to more chronic pollution events, which on the basis of the reviewed literature seem to account for a much greater amount of pollution in the marine environment.

As it is not possible to determine the source of the most damaging pollutant effects on red-throated diver, and due to some of these pollution effects being historical in nature, as well as many unknowns on how much of an effect each pollution source has on birds, a comparison of each activity is not possible for pollution.

5.5.6 Summary of relative impacts

A summary of how each of the activities/pressures considered with regard to red-throated diver in the above sections compare with offshore wind is presented in Table 5-10.

Based on the literature review, which showed a general lack of information regarding prey availability impacts for this species, it is difficult to separate impacts of fisheries (Section 5.5.1.4) and climate change (Section 5.5.1.3) from offshore wind (the impact of which is indirect; through displacement) (Section 5.5.1.2). On the basis of literature for other species (i.e. kittiwake (Section 5.2.1)) suggesting that climate change is the main driver behind prey availability reductions, and the fact that this operates at a much wider spatial scale than fisheries, it could be assumed that the same is true for red-throated diver. It is acknowledged that such a surrogate may not be appropriate, given the different ecological niches
occupied by these species, and that the certainty in attempting to rank these predictions is low. On this basis, whilst it is unlikely to be true, this assessment concludes that prey availability impacts for climate change and fisheries cannot reliably be separated for this species from those caused by offshore wind, thus they are considered to be similar. It is “near certain” (99-100% probability) that red-throated diver is sensitive to all three activities.

Due to the low exposure for this species, sand and gravel extraction (Section 5.5.1.5) is considered “likely” (66-100% probability) to have a lower effect on red-throated diver prey availability in the wider North Sea area than offshore wind. The evidence presented in the literature review suggests that it is “very likely” (90-100% probability) that the other activities considered in Section 3 have a lower effect on red-throated diver prey availability than offshore wind, and are therefore unlikely to contribute significantly to red-throated diver prey availability impacts at the wider North Sea level, though it is accepted that this situation may be different at a local level.

Like many species of seabird, red-throated diver are potential victims of bycatch from fishing activities (Section 5.5.2). It is considered “virtually certain” (99-100% probability) that none of the other pressures identified in Section 3 result in red-throated diver mortality due to bycatch, including offshore wind. As a result, bycatch impacts from fisheries are considered to be considerably larger than the equivalent impact of offshore wind (i.e. zero). As stated in Section 5.5.2, it has been suggested that red-throated diver may be susceptible to bycatch as a result of aquaculture, but this has not been assessed due to a lack of data.

The impact of airborne collision mortality on red-throated diver due to offshore wind is considered to be negligible due to the near 100% displacement of this species within offshore wind farms (Section 5.5.3.1). At the present time, the same is true of ocean renewable energy, since deployment levels (and thus exposure) are very low, though it may be that red-throated diver are sensitive to underwater collision impacts in the future (Section 5.5.3.2). Certainty of the exact level of these impacts is described as “likely” (66-100% probability), whilst the probability of the relative classification (i.e. similar levels of collision are expected from offshore wind and ocean renewable energy at the time of writing) is “very likely” (90-100% probability) due to known aspects of red-throated diver foraging ecology.

For disturbance and displacement, it is considered that red-throated diver is highly sensitive to this effect with regard to all activities/pressures (Section 5.5.4). Offshore wind requires the permanent placement of very tall structures across large areas of subtidal habitat for an extended period of time (25 years, or more if repowering is considered), a practice that is widespread across many parts of the North Sea, of which some overlap with non-breeding red-throated diver habitat. On this basis, and based on the literature review, it is considered “likely” (66-100% probability) that offshore wind may have a greater disturbance and displacement effect on red-throated diver than all other activities described in Section 3, though it is accepted that the magnitude of these impacts will vary substantially by location.

Table 5-10. Comparison of activities/pressures on red-throated diver with pressures resulting from offshore wind development in the present-day scenario.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Prey Availability</th>
<th>Bycatch</th>
<th>Collision Risk</th>
<th>Disturbance and Displacement</th>
<th>Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Similar to offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Similar to offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Activity/Pressure</td>
<td>Prey Availability</td>
<td>Bycatch</td>
<td>Collision Risk</td>
<td>Disturbance and Displacement</td>
<td>Pollution</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------</td>
<td>---------</td>
<td>----------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Less than offshore wind</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Ocean Renewable Energy</td>
<td>N/A</td>
<td>N/A</td>
<td>Similar to offshore wind</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Military</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Shipping</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Less than offshore wind</td>
<td>Comparison not possible</td>
</tr>
<tr>
<td>Pollution Sources</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Comparison not possible</td>
</tr>
</tbody>
</table>
6 Estimation of Future Anthropogenic Activity Impact Levels

In this Section the future development of the relative contribution of all activities is assessed per pressure. This is based on the total level of impact that is determined in Section 5 and the estimated volumes of the activities in relation to offshore wind for the present-day and the future scenarios (Table 6-1).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Now</th>
<th>2023</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>Moderate volume</td>
<td>High volume</td>
<td>Very high volume</td>
</tr>
<tr>
<td>Shipping</td>
<td>Higher than OW</td>
<td>Higher than OW</td>
<td>Same as OW</td>
</tr>
<tr>
<td>Oil &amp; gas exploitation</td>
<td>Higher than OW</td>
<td>Higher than OW</td>
<td>Same as OW</td>
</tr>
<tr>
<td>Sand and gravel extraction</td>
<td>Lower than OW</td>
<td>Lower than OW</td>
<td>Much lower than OW</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Much lower than OW</td>
<td>Much lower than OW</td>
<td>Lower than OW</td>
</tr>
<tr>
<td>Military</td>
<td>Same as OW</td>
<td>Lower than OW</td>
<td>Much lower than OW</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Much lower than OW</td>
<td>Much lower than OW</td>
<td>Much lower than OW</td>
</tr>
<tr>
<td>Land based sources</td>
<td>Lower than OW</td>
<td>Much lower than OW</td>
<td>Much lower than OW</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Higher than OW</td>
<td>Higher than OW</td>
<td>Same as OW</td>
</tr>
<tr>
<td>Offshore islands</td>
<td>Much lower than OW</td>
<td>Much lower than OW</td>
<td>Lower than OW</td>
</tr>
<tr>
<td>Climate change</td>
<td>Much lower than OW</td>
<td>Lower than OW</td>
<td>Same as OW</td>
</tr>
</tbody>
</table>

In the following Sections per pressure it is estimated whether the activity has more, similar or less impact on the marine species than offshore wind in the present day, 2023 and 2030.

6.1 Harbour Porpoise

6.1.1 Underwater Noise

Table 6-2 summarises the potential overall effect from each activity generating impulsive underwater noise in 2023 and 2030, based on current effect levels and the predicted growth or decline of the activity in the future. Due to the strong drive for more renewable energy in the North Sea, oil and gas production is in decline. However, the decommissioning phases of the projects currently in the North Sea will also generate significant levels of underwater noise, and therefore as a whole, there is expected to be no change in underwater noise effects in 2023 so the relative impact will also be more than offshore wind. It is expected that there may be small decline in 2030 if the level of seismic exploration decreases with decreasing demand, in combination with increasing offshore wind activity the relative impact will decrease to similar to offshore wind.

Underwater noise from military activities will not change from current levels and noise sources, the relative impact will approximately stay the same in 2023 (less than offshore wind) and will be considerably less than offshore wind in 2030 because of the high increase of offshore wind. There is little information on the further growth of both Ocean renewable energy or from offshore islands, but it is expected that both industries will grow in the future. The total ‘volume’ of offshore wind will be much higher than for these activities, so the relative impact will still be less than offshore wind in 2030.

Table 6-2 Summary of impulsive underwater noise effects in the future
Table 6-3 summarises the potential overall effect from each activity generating non-impulsive underwater noise in 2023 and 2030. Non-impulsive underwater noise effects on harbour porpoise are expected to still be dominated by shipping in both 2023 and 2030. While it is expected that ships will get quieter in the future, this will not happen before 2030. As a whole, the shipping industry will continue to increase and therefore in both 2023 and 2030 will generate a large amount of non-impulsive noise in the North Sea. There is also the potential that the opening of the Arctic to shipping in the future will increase shipping within the North Sea, but there are many uncertainties associated with that possibility. Because of the increase in offshore wind in 2030 the relative impact will be a bit lower (more than offshore wind). Other major contributors to underwater noise effects in 2023 and 2030 include fisheries (vessel and trawling noise) and the oil and gas industry. There is no evidence that the fisheries industry in the North Sea will reduce in the future, and may increase with continued population growth, and will therefore continue to generate high levels of non-impulsive noise in the North Sea but the relative impact will decrease (to similar to offshore wind) because of the increase of offshore wind. Both fisheries and shipping are permanent activities within the North Sea, causing a continued high level of noise exposure for harbour porpoise.

Underwater noise from gravel extraction will not change from current levels and noise sources, but the relative impact will decrease (to less than offshore wind) because of the increase of offshore wind in 2030. There is little information on the further growth of both Ocean renewable energy or from offshore islands, but it is expected that both industries will grow in the future, therefore the relative impact will be less than offshore wind in 2030.

Table 6-3 summarises the potential overall effect from each activity generating non-impulsive underwater noise in 2023 and 2030.

### Table 6-3 Summary of non-impulsive underwater noise effects in the future

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative impact now</th>
<th>Relative impact 2023</th>
<th>Relative impact 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil &amp; gas</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Military</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Considerably less than offshore wind</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
</tbody>
</table>

6.1.2 Bycatch

Table 6-4 summarises the potential overall effect from the fisheries industry on bycatch in 2023 and 2030, based on current effect levels and the predicted growth or decline of the activity in the future.
A further study of the population level of effect on harbour porpoise as a result of offshore wind farm development in the whole North Sea (with a population loss due to a reduction in the vital rates of harbour porpoise) indicates that there is a 50% chance that the harbour porpoise population will be reduced by 2,937 to 5,691 individuals by 2030 (or 0.85% to 1.65% of the current harbour porpoise population level) (Heinis et al., 2019). This is considerably less than the expected level of population loss of harbour porpoise each year, with the expectation that the current level of loss (more than 6,160 individuals per year) will not change.

Since 2003, total fishing efforts have been in decline across the North Sea. However, the number of landings from static gear (such as gillnets) has remained constant (ICES, 2017). It is therefore expected that the number of harbour porpoise bycaught by fisheries will not change from current levels.

### Table 6-4 Summary of bycatch effects in the future

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative impact now</th>
<th>Relative impact 2023</th>
<th>Relative impact 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
</tbody>
</table>

#### 6.1.3 Displacement

Table 6-5 summarises the potential overall effect from each activity having displacement effects on harbour porpoise in 2023 and 2030, based on current effect levels and the predicted growth or decline of the activity in the future.

The largest contributor of displacement effects will continue to be from fisheries in 2023 and 2030. This is due to the potential increase in fisheries effort with global population change, and due to the large number of harbour porpoise prey species that are lost through fisheries. The relative impact will be more than offshore wind in all scenarios. The relative impact of the other activities will decrease in 2030 due to the increase of offshore wind. The future effects of climate change on harbour porpoise are still unknown, and there is therefore no way to predict what these effects may be in the future, although it should be noted that the effects will increase with time.

### Table 6-5 Summary of displacement effects in the future

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative impact now</th>
<th>Relative impact 2023</th>
<th>Relative impact 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
</tr>
<tr>
<td>Oil &amp; gas</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Sand and gravel extraction</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Climate change</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

#### 6.1.4 Collision Risk

Table 6-6 summarises the potential overall effect from each activity on harbour porpoise fatal collision risk in 2023 and 2030, based on current effect levels and the predicted growth or decline of the activity in the future.

The largest contributors of fatal collisions to harbour porpoise will continue to be shipping, oil and gas and fisheries. This is due to the large number of vessel presence of these industries in the North Sea, and the
indication that this will not change in the future, and the possibility that shipping may increase in the future. The relative impact of fisheries and oil and gas will decrease (to similar to offshore wind) due to the increase in offshore wind in 2030. Military activities will not change from current levels, the relative impact will approximately stay the same in 2023 (less than offshore wind) and will be considerably less than offshore wind in 2030 because of the high increase of offshore wind. For Ocean renewable energy developments, it is still unknown what the potential for fatal collisions may be in the future. Until the level of development in the North Sea of wave and tidal energy is better understood, as well as the effect from these devices, the potential effect on the harbour porpoise population in the future is unknown.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative impact now</th>
<th>Relative impact 2023</th>
<th>Relative impact 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
<tr>
<td>Oil &amp; gas</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
<tr>
<td>Sand and gravel extraction</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Offshore Islands</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Military</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Considerably less than offshore wind</td>
</tr>
<tr>
<td>Ocean renewable energy</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

### 6.1.5 Pollution

As stated in Section 5.1.5, it is currently unknown whether the effects of pollution on the harbour porpoise population is increasing, decreasing, or if there has been no change. There is therefore no way to determine what those effects may be in the future, although it could be expected that the marine litter pollution (including ghost fishing gear) will increase in the future with increased population growth. It is also currently unknown which activity is causing the highest level of damage, although it is noted that pollutant discharge effects are lower than that of the effects on the population associated with the construction industry (Reijnders et al., 2009).

### 6.2 Kittiwake

#### 6.2.1 Prey Availability

Prey availability impacts on kittiwake (Section 5.2.1) are currently very high and are predicted to remain so in 2023 and 2030. This is due mainly to impacts of climate change (Section 5.2.1.2). There is no evidence that effects on kittiwake due to climate change will reduce in magnitude in the future. This report predicts a similar situation to be “virtually certain” (99-100%) in 2023 (similar effects), and a worse situation “very likely” (90-100% probability) by 2030. It is considered climate change will continue to be a much greater contributor to kittiwake prey availability effects than offshore wind despite the increased offshore wind deployment planned for 2023 and 2030 (Section 5.2.1.1).

Climate change effects on kittiwake prey availability are considered to be moderately exacerbated by fisheries activities (Section 5.2.1.3). Whilst the future trend of the fisheries industry is uncertain and is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9), the fact that this is a contributory rather than a primary cause does not affect the overall
impact level of prey availability impacts on kittiwake. Fisheries has been classified as a higher contributor to the overall impact of prey availability on kittiwake than offshore wind in all time periods under consideration. It is acknowledged that due to fisheries activities being particularly concentrated in particular areas, the level of impact will vary geographically, and peak at times where particular fisheries are active. However, it is considered that prey availability impacts due to offshore wind are relatively small (Section 5.2.1.1), so the certainty that fisheries is a larger contributor to this impact is “very likely” (90-100% probability).

Sand and gravel extraction (Section 5.2.1.4) is estimated to have a similar effect on kittiwake prey availability in the wider North Sea area, both now, as well as the 2023 and 2030 scenarios based on the “about as likely as not” (33-66%) prediction that activities will remain at a similar level until 2030 (despite the fact that offshore wind deployment is predicted to increase). This will vary by location and time of year, and as only a small amount of information was available on the impacts caused by this activity, this conclusion is considered to be “about as likely as not” (33-66% probability).

The evidence presented in the literature review indicates that the other activities considered in Section 3 are unlikely to contribute significantly to kittiwake prey availability impacts at the wider North Sea level, although it is acknowledged that this situation may be different at a local level. Whilst there is a degree of uncertainty with regard to the future growth/reduction of some of these activities, this does not result in uncertainty with regard to relative contributions due to the very large contribution of climate change, and the high certainty that this is the dominant pressure with regard to kittiwake prey availability.

Table 6-7 summarises the relative impacts of all activities that are considered to have a greater than or equal contribution to kittiwake prey availability impacts compared to offshore wind in the three time periods assessed.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
</tbody>
</table>

6.2.2 Bycatch

Fisheries is the only activity considered in Section 3 that causes a bycatch impact (Section 5.2.2). Whilst the future trend of the fisheries industry is not well known and is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9), this does not affect the contents of Table 6-8, as bycatch is not an impact caused by other activities.

Table 6-8. Impacts of relevant activities/pressures on kittiwake bycatch considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
</tbody>
</table>

### 6.2.3 Collision Risk

The impact of collision mortality on kittiwake in the present day results largely from offshore wind (Section 5.2.3), and due to a general lack of sensitivity of kittiwake to collision with offshore structures/assets other than wind turbines (including ocean renewable energy devices), will continue to be the case in both 2023 and 2030 (Table 6-9). This is particularly true since substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
</tr>
</tbody>
</table>

### 6.2.4 Disturbance and Displacement

Based on the literature review (Section 5.2.4), it is considered that offshore wind may have a slightly greater disturbance and displacement effect on kittiwake than all other activities described in Section 3 at the wider North Sea level, though it is accepted that the magnitude of these impacts will vary substantially by location. However, it is still considered that the effect of disturbance and displacement is relatively weak on the basis that kittiwake are known to be relatively tolerant to human activity, and that collision risk with wind turbines (Section 5.2.3) is high for this species (which indicates that high numbers of birds are not displaced by offshore wind farms).

On the basis that substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030 it is expected that disturbance and displacement of kittiwake due to offshore wind will remain higher than for all other activities in 2023 and 2030 (Table 6-10).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Shipping</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
</tr>
<tr>
<td>Military</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Ocean Renewable Energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
</tbody>
</table>
6.2.5 Pollution

As explained in Section 5.2.5 it is not possible to explore the relative contributions of different activities/pressures to these effects.

6.3 Guillemot

6.3.1 Prey Availability

Assessing the relative importance of prey availability impacts on guillemot (Section 5.3.1) is challenging. Because the overall population is increasing in size, it could be argued that prey availability is not currently a substantial issue for this species. However, it is possible that without prey availability impacts, overall population growth could be greater (and declining trends in some areas could reverse), though it is not possible to demonstrate this.

Based on the literature review, fisheries (Section 5.3.1.4) and climate change (Section 5.2.1.2) are considered to represent greater influences on guillemot prey availability both now and in future scenarios compared to offshore wind. On the basis of literature for other species (i.e. kittiwake (Section 5.2.1)) suggesting that climate change is the main driver behind prey availability reductions, it is assumed that the same is true for guillemot.

With respect to climate change, this report predicts a similar situation to be “virtually certain” (99-100%) in 2023 (similar effects), and a worse situation “very likely” (90-100% probability) by 2030. It is considered climate change is a much greater contributor to guillemot prey availability effects than offshore wind, and that this will continue to remain the case despite the increased offshore wind deployment planned for 2023 and 2030 (Section 5.3.1.2). This prediction is “virtually certain” (99-100% probability).

The future trend of the fisheries industry is not clear and is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9). Fisheries has been classified as a higher contributor to the overall impact of prey availability on guillemot than offshore wind in all time periods under consideration, though the level of impact will vary geographically, and peak at times where particular fisheries are active. It is considered that prey availability impacts due to offshore wind are relatively small (Section 5.3.1.2), so the certainty that fisheries is a larger contributor to this impact is “virtually certain” (99-100% probability).

Sand and gravel extraction is estimated to have a similar effect to offshore wind on guillemot prey availability in the wider North Sea area (Section 5.3.1.5) in the present day, as well as the 2023 and 2030 scenarios based on the “about as likely as not” (33-66%) prediction that activities will remain at a similar level until 2030 (despite the fact that offshore wind deployment is predicted to increase). This will vary by location and time of year, and as only a small amount of information was available on the impacts caused by this activity, this conclusion is considered to be “about as likely as not” (33-66% probability).

The evidence presented in the literature review indicates that the other activities considered in Section 3 have a lower effect on guillemot prey availability than offshore wind, and are therefore unlikely to contribute significantly to guillemot prey availability impacts at the wider North Sea level compared to climate change and fisheries, though it is accepted that this situation may be different at a local level. Whilst there is a degree of uncertainty with regard to the future growth/reduction of some of these activities, this does not result in uncertainty with regard to relative contributions due to the very large contribution of climate change to this pressure, and the high certainty that this is the dominant pressure with regard to guillemot prey availability based on the literature examined.
Table 6-11 summarises the relative impacts of all activities that are considered to have a greater than or equal contribution to guillemot prey availability impacts compared to offshore wind in the three time periods assessed.

**Table 6-11. Impacts of relevant activities/pressures on guillemot prey availability considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.**

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
</tbody>
</table>

### 6.3.2 Bycatch

Fisheries is considered to be the only activity considered in Section 3 that causes a bycatch impact on guillemot (Section 5.3.2). The future trend of the fisheries industry is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9). This does not affect the contents of Table 6-12, as bycatch is not an impact caused by other activities.

**Table 6-12. Impacts of relevant activities/pressures on guillemot bycatch considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
</tbody>
</table>

### 6.3.3 Collision Risk

The impact of airborne collision mortality on guillemot due to offshore wind is considered to be negligible due to the known flight height distribution of this species (Section 5.3.3). This will continue to be the case in both 2023 and 2030 regardless of the predicted increased deployment of offshore wind (Section 3.1.1) and is predicted with “near certain” (99-100% probability) confidence.

It is assumed that ocean renewable energy will moderately increase from virtually zero in the present day in the period up to 2023, with large increases in deployment potential possible by 2030. The likelihood for both predictions is “about as likely as not” (33-66% probability) based on the uncertainty surrounding commercial viability of existing devices and projects. On this basis, increases in guillemot mortality due to underwater collision with ocean renewable energy devices have been predicted for 2030, which would result in a greater collision risk compared to offshore wind (Table 6-13). However, this is currently a theoretical risk with no understanding of likely avoidance rates, so is considered “about as likely as not” (33-66% probability) in terms of confidence.

**Table 6-13. Impacts of relevant activities/pressures on guillemot collision risk considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.**

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Renewable Energy</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>More than offshore wind</td>
</tr>
</tbody>
</table>
6.3.4 Disturbance and Displacement

For disturbance and displacement, it is considered that guillemot are moderately sensitive to this effect with regard to all activities/pressures (Section 5.3.4), and there is no single activity that is clearly a dominant contributor to this impact at the wider North Sea level. It is considered that offshore wind may have a greater disturbance and displacement effect on guillemot than all other activities described in Section 3, though it is accepted that the magnitude of these impacts will vary substantially by location.

On the basis that substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030 it is expected that disturbance and displacement of guillemot due to offshore wind will remain higher than for all other activities in 2023 and 2030 (Table 6-14).

Table 6-14. Impacts of relevant activities/pressures on guillemot disturbance and displacement considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Shipping</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Military</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Ocean Renewable Energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
</tbody>
</table>

6.3.5 Pollution

As explained in Section 5.3.5, it is not possible to explore the relative contributions of different activities/pressures to these effects.

6.4 Lesser Black-backed Gull

6.4.1 Prey Availability

Assessing the relative importance of prey availability impacts on lesser black-backed gull (Section 5.4.1) is challenging. Because the overall population is increasing in size, it could be argued that prey availability is not currently a substantial issue for this species, especially with regard to the increasing numbers of this species found in urban areas. However, it is possible that without prey availability impacts, overall population growth could be greater (and declining trends in many coastal areas could reverse), though it is not possible to demonstrate this.

Based on the literature review, both fisheries (Section 5.4.1.3) and climate change (Section 5.4.1.2) are considered to represent greater influences on lesser black-backed gull prey availability both now and in future scenarios compared to offshore wind. There is considerable difficulty and uncertainty in disentangling the combined effect on lesser black-backed gull prey availability of fisheries and climate change without appropriate research. On the basis of literature for other species (i.e. kittiwake (Section 5.2.1)) suggesting that climate change is the main driver behind prey availability reductions, suggesting
that climate change is the main driver behind prey availability reductions, it is assumed that the same is true for lesser black-backed gull despite its flexibility with regard to prey.

With respect to climate change, this report predicts a similar situation to be “virtually certain” (99-100%) in 2023 (similar effects), and a worse situation “very likely” (90-100% probability) by 2030. The future trend of the fisheries industry is not well known and is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9).

It is considered “virtually certain” (99-100% probability) that climate change is a much greater contributor to lesser black-backed gull prey availability effects than offshore wind, and that this will continue to remain the case despite the increased offshore wind deployment planned for 2023 and 2030 (Section 5.4.1.1). The same applies to fisheries, though it is acknowledged that the level of impact will vary geographically, and possibly peak at times where particular fisheries are active.

Sand and gravel extraction is estimated to have a similar effect to offshore wind on lesser black-backed gull prey availability in the wider North Sea area in the present day (Section 5.4.1.4), as well as the 2023 and 2030 scenarios based on the “about as likely as not” (33-66% probability) prediction that activities will remain at a similar level until 2030 (despite the fact that offshore wind deployment is predicted to increase). This will vary by location and time of year, and as only a small amount of information was available on the impacts caused by this activity, this conclusion is considered to be “about as likely as not” (33-66% probability).

The other activities considered in Section 3 are unlikely to contribute significantly to black-backed gull prey availability impacts at the wider North Sea level compared to climate change and fisheries, though it is accepted that this situation may be different at a local level. Whilst there is a degree of uncertainty with regard to the future growth/reduction of some of these activities, this does not result in uncertainty with regard to relative contributions due to the very large contribution of climate change and fisheries to this pressure, and the high certainty that these are the dominant pressures with regard to black-backed gull prey availability based on the literature examined.

Table 6-15 summarises the relative impacts of all activities that are considered to have a greater than or equal contribution to lesser black-backed gull prey availability impacts compared to offshore wind in the three time periods assessed.

Table 6-15. Impacts of relevant activities/pressures on lesser black-backed gull prey availability considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
<tr>
<td>Fisheries</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
<td>More than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
</tbody>
</table>

6.4.2 Bycatch

Fisheries is considered to be the only activity considered in Section 3 that causes a bycatch impact on lesser black-backed gull (Section 5.4.2). The future trend of the fisheries industry is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9). This does not affect the contents of Table 6-16, as bycatch is not an impact caused by other activities.
6.4.3 Collision Risk

The impact of collision mortality on lesser black-backed gull in the present day results largely from offshore wind (Section 5.4.3), and due to a general lack of sensitivity of lesser black-backed gull to collision with offshore structures/assets other than wind turbines (including ocean renewable energy devices), will continue to be the case in both 2023 and 2030. This prediction is “near certain” (99-100% probability). This is particularly true since substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030 (Table 6-17).

6.4.4 Disturbance and Displacement

Based on the literature review in Section 5.4.4, it is considered that offshore wind may have a slightly greater disturbance and displacement effect on lesser black-backed gull than all other activities described in Section 3 at the wider North Sea level, though it is accepted that the magnitude of these impacts will vary substantially by location. It is considered that the effect of offshore wind is relatively weak on the basis that gulls are known to be relatively tolerant to human activity, and that collision risk with wind turbines (Section 5.4.3) is high for this species (which indicates that high numbers of birds are not displaced by offshore wind farms).

On the basis that substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030 it is expected that disturbance and displacement of lesser black-backed gull due to offshore wind will remain higher than for all other activities in 2023 and 2030 (Table 6-18).

Table 6-16. Impacts of relevant activities/pressures on lesser black-backed gull bycatch considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
</tbody>
</table>

Table 6-17. Impacts of relevant activities/pressures on lesser black-backed gull collision risk considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean renewable energy</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
</tr>
</tbody>
</table>

Table 6-18. Impacts of relevant activities/pressures on lesser black-backed gull disturbance and displacement considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Shipping</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Considerably less than offshore wind</td>
<td>Considerably less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
</tbody>
</table>
6.4.5 Pollution

As explained in Section 5.2.5, it is not possible to explore the relative contributions of different activities/pressures to these effects.

6.5 Red-throated Diver

6.5.1 Prey Availability

Assessing the relative importance of prey availability impacts on red-throated diver (Section 5.5.1) is challenging due to the highly limited availability of information on the subject in the literature. As a result, this assessment could not separate climate change, fisheries and offshore wind impacts on red-throated diver prey availability. As this is the case in the present day, it is also the case for both future scenarios.

Sand and gravel extraction is estimated to have a lesser effect to offshore wind on red-throated diver prey availability in the wider North Sea area (Section 5.5.1.5) in the present day, as well as the 2023 and 2030 scenarios based on the “about as likely as not” (33-66%) prediction that activities will remain at a similar level until 2030 (despite the fact that offshore wind deployment is predicted to increase). This will vary by location and time of year, and as only a small amount of information was available on the impacts caused by this activity. However, as there is very limited spatial overlap between red-throated diver habitat and this activity this conclusion is considered to be “likely” (66-100% probability).

The evidence presented in the literature review indicates that the other activities considered in Section 3 have a lower effect on red-throated diver prey availability than offshore wind, and are therefore unlikely to contribute significantly to red-throated diver prey availability impacts at the wider North Sea level compared to climate change and fisheries, though it is accepted that this situation may be different at a local level. There is a degree of uncertainty (“about as likely as not”, (33-66% probability)) surrounding the future growth/reduction of some of these activities and therefore the relative contributions to prey availability for this species. This is because the prediction of the very large contribution of climate change to this pressure is uncertainty for this species due to a lack of species-specific information.

Table 6-19 summarises the relative impacts of all activities that are considered to have a greater than or equal contribution to red-throated diver prey availability impacts compared to offshore wind in the three time periods assessed.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
</tr>
<tr>
<td>Sand and Gravel Extraction</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
<td>Less than offshore wind</td>
</tr>
</tbody>
</table>

Table 6-19. Impacts of relevant activities/pressures on red-throated diver prey availability considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.
6.5.2 Bycatch

Fisheries is considered to be the only activity considered in Section 3 that causes a bycatch impact on red-throated diver (Section 5.5.2). The future trend of the fisheries industry is presumed “about as likely as not” (33-66% probability) to remain at current levels in 2023 and 2030 (Section 3.1.9). This does not affect the contents of Table 6-20, as bycatch is not an impact caused by other activities that were assessed. There was insufficient information to assess the potential impact of aquaculture on red-throated diver bycatch.

Table 6-20. Impacts of relevant activities/pressures on red-throated diver bycatch considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Relative Impact Now (Section 5)</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
<td>Considerably more than offshore wind</td>
</tr>
</tbody>
</table>

6.5.3 Collision Risk

The impact of airborne collision mortality on red-throated diver due to offshore wind is considered to be negligible due to the near 100% displacement of this species from within offshore wind farms (Section 5.5.3). This is predicted to continue to be the case in both 2023 and 2030 regardless of the predicted increased deployment of offshore wind (Section 3.1.1) and is predicted with “likely” (66-100% probability) confidence.

Table 6-21. Impacts of relevant activities/pressures on red-throated diver collision risk considered to be greater than or equal to relative contribution of offshore wind, in present day, 2023 and 2030.

<table>
<thead>
<tr>
<th>Activity/Pressure</th>
<th>Relative Impact Now</th>
<th>Relative Contribution 2023</th>
<th>Relative Contribution 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Renewable Energy</td>
<td>Similar to offshore wind</td>
<td>Similar to offshore wind</td>
<td>More than offshore wind</td>
</tr>
</tbody>
</table>

6.5.4 Disturbance and Displacement

For disturbance and displacement, it is considered that red-throated diver are highly sensitive to this effect with regard to all activities/pressures (Section 5.5.4). It is considered that offshore wind may have a greater disturbance and displacement effect on red-throated diver than all other activities described in Section 3, though it is accepted that the magnitude of these impacts will vary substantially by location.

On the basis that substantial increases in offshore wind deployment are considered “very likely” (90-100% probability) in 2023, and “likely” (66-100% probability) in 2030 it is expected that disturbance and displacement of red-throated diver due to offshore wind will remain higher than for all other activities in 2023 and 2030 (Table 6-22).
### 6.5.5 Pollution

As explained in Section 5.3.5, it is not possible to explore the relative contributions of different activities/pressures to these effects.
7 Conclusions

7.1 Harbour Porpoise

When considering what the future contribution of effects on the North Sea harbour porpoise population, it is important to consider what those effects are now. A literature review has shown the current impact of the different pressures and activities. Based on the expected future developments in activities the development in the level of impact was assessed. In this section the overall conclusions are described.

The previous sections have shown that the activities that have the biggest effect on harbour porpoise is fisheries, through primarily bycatch, but also through noise levels and the effect of displacement through loss of prey species. Another major contributing industry to effects on harbour porpoise is from shipping, which generates high levels of non-impulsive noise throughout the North Sea, which has permanently changed the underwater soundscape of the North Sea. When comparing these activities to that of offshore wind farm development, it is important to consider the timeframe at which these activities are undertaken. Underwater noise from offshore wind farms is temporary (although it can be assumed ‘permanent’ in the coming years, when a lot of wind farms will be built in the North Sea), whether from piling of the wind turbines, or from other construction and operation related activities, whereas both shipping and fisheries represent a constant level of activities in the North Sea, meaning there is no period of time where harbour porpoise are not being exposed to effects from these industries.

When taking these effects forward in the future, the predicted change in industry up to 2023 and 2030 were considered. There is little difference in the future effects of these activities on the harbour porpoise population in relation to offshore wind farm development, with the potential that the ocean renewable energy and offshore islands industries may increase in the future, increasing their relative level of effect on the population, but the relative impact will still be less than offshore wind because of the strong increase in offshore wind. There is the potential that the effects from the oil and gas industry may decrease over time, as the demand for new oil and gas platforms reduces. Although it should be noted that with the decline of the demand for oil and gas, there will be an increase in decommissioning activities of the infrastructure already in place, and so overall the effects from the industry when considered as a whole may only decrease slightly. While it is unknown what the effect of climate change is having on the harbour porpoise population, it is thought that it will have effects relating to the change of prey distribution. There is little evidence currently available to determine what effect climate change is having on harbour porpoise, and therefore it has not been possible to relate those effects to that of offshore wind farm development. However, whatever those effects may be now, they will increase in the future.

As stated above, currently, the biggest threat to the harbour porpoise population is bycatch from the fisheries industry, which is causing a significant level of population decline across the North Sea. As there is no indication that the level of fisheries activities will decline in the future, it is considered that in both 2023 and 2030, bycatch from fisheries will remain as the biggest threat to the harbour porpoise population of the North Sea, representing a considerably higher effect than from offshore wind farm development.

7.2 Seabirds

Based on expert opinion following a review of the literature, it is concluded that prey availability effects due to climate change is the pressure/pathway that in the present day appears to have the largest impact on kittiwake, guillemot and lesser black-backed gull at the wider North Sea level, and is likely to be responsible for a substantially greater effect than impacts resulting from any of the other activities. For all seabirds it is largely expected that climate change impacts will become more severe in the future as both temperatures, and possibly the rate of increase, become greater, and extreme weather events become more frequent. Whilst there is a high certainty in the ranking of most severe activities and pressures for
kittiwake, there is less certainty for guillemot and lesser black-backed gull, and less still for red-throated diver, to the extent where for the final species, prey availability impacts could not be ranked. This is due to the amount of relevant literature identified.

All other activities are considered to be currently having a much lower effect on the four seabird species, especially at the wider North Sea level relative to climate change. It should be noted that there is potential for localised impacts, particularly due to bycatch (all species, but especially guillemot), displacement by offshore wind farms and other activities (red-throated diver) bycatch, collision with offshore wind turbines (kittiwake and lesser black-backed gull) and collision with ocean renewable energy devices (guillemot and red-throated diver), to be significant.

In the two future scenarios considered by this report, there are no substantial changes anticipated in terms of what the dominant pressures acting on seabirds will be, though it is likely that anthropogenic pressures in general will increase in the marine environment. As kittiwake is currently undergoing substantial population decline over much of its range (Section 4.2), it is considered to be a highly sensitive and fragile population. Whilst the guillemot population is currently increasing at the European level (Section 4.3), and is more flexible with regard to prey, which in theory makes it more robust, it is still considered that the predicted increase in marine anthropogenic activity in future will still render it highly susceptible to population declines. Lesser black-backed gull, whilst apparently increasing in number across Europe overall (Section 4.4), may become increasingly common as an urban species, and less so in coastal and marine environments if recent trends continue. This will likely be expedited by increases in anthropogenic marine pressures. The future of red-throated diver is less clear due to a lack of identified research into projected future trends, though as a bird reliant predominantly on Arctic coastal areas for breeding, is presumably going to be susceptible to climate change driven declines in the future, hastening already existing declines in the European population (Section 4.5).

7.3 Further Method Development

This report describes a first attempt of developing a method to assess the impact of activities on marine species in relation to offshore wind. For efficient use in the future, it is recommended to develop the method further. The following actions could be considered:

- There is a high degree of uncertainty regarding the development of the activities in the coming years. Further development of knowledge on existing activities (e.g. using http://www.emodnet.eu/) is recommended;
- There are geographical differences in the North Sea, some activities take place more often in a certain area. This has not been considered in the current report, maybe the use of North Sea regions could be considered, or another way to include the geographical differences in activities;
- In the current report the temporal differences have not been considered for all activities, due to a lack of information. It would make the method more accurate when temporal differences could be included in more detail;
- It was recommended by one of the experts to include fishing days in the assessment, to have a more accurate exposure rate on that activity. This would also ask for a more accurate exposure rate for the other activities;
- The “moderate” descriptor covers a wide range of possible sensitivities and impact levels. It may be sensible to investigate whether sub-dividing this category is helpful;
- It may be helpful to further quantify levels of uncertainty in a future method, and to devise a method to provide additional transparency regarding how particular conclusions have been reached; and
- A further option to increase our knowledge on the relative contributions of each the activities included in this report, and the impact that these have on the population level as a whole, could be to undertake
theoretical population modelling. This modelling should include impacts from each of these industries to determine the overall impact to the population, as well as the contributor that is causing the highest level of impact. This can be used to understand the best way forward of limiting the effect on the population in the future.
8 References

General Sections


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