
# Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

# Volume 2, Chapter 4: Marine Mammals

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# Table of Contents



# List of Tables

# List of Figures

# Annexes

| Annex | Heading |
|---|---|
| 5.4.1 | Marine Mammals Technical Report |

# Glossary

| Term | Definition |
|---|---|
| Commitment | A term used interchangeably with mitigation. Commitments are embedded mitigation measures. Commitments are either primary (design) or tertiary (Inherent) and embedded within the assessment at the relevant point in the Environmental Impact Assessment (EIA) (e.g. at Scoping or Preliminary Environmental Information Report (PEIR)). The purpose of Commitments are to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms. |
| Cumulative effects | The combined effect of Hornsea Four in combination with the effects from a number of different projects, on the same single receptor/resource. |
| Cumulative impact | Impacts that result from changes caused by other past, present or reasonably foreseeable actions together with Hornsea Four. |
| Development Consent Order (DCO) | An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP). |
| Effect | Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria. |
| EIA Directive | European Union Directive 85/337/EEC, as amended by Directives 97/11/EC, 2003/35/EC and 2009/31/EC and then codified by Directive 2011/92/EU of 13 December 2011 (as amended in 2014 by Directive 2014/52/EU. |
| EIA Regulations | The Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 (as amended). |
| Environmental Impact Assessment (EIA) | A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report. |
| Export cable corridor (ECC) | The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Four array area to the Creyke Beck National Grid substation, within which the export cables will be located. |
| Habitats Regulations Assessment (HRA) | A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European conservation sites and Ramsar sites. The process consists of up to four stages of assessment: screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI). |
| High Voltage Alternating Current (HVAC) | High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction. |
| Hornsea Four | The proposed Hornsea Project Four offshore wind farm project; the term covers all elements within the DCO (i.e. both the offshore and onshore components). |

| Term | Definition |
|---|---|
| Mitigation | A term used interchangeably with Commitment(s) by Hornsea Four. Mitigation measures (Commitments) are embedded within the assessment at the relevant point in the EIA (e.g. at Scoping or PEIR). |
| Permanent Threshold Shift (PTS) | A total or partial permanent loss of hearing at a particular frequency caused by some kind of acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity at that frequency. |
| Sound Exposure Level (SEL) | The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics. |
| Sound Pressure Level (SPL) | The sound pressure level or SPL is an expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 μPa for water. |
| Temporary Threshold Shift (TTS) | Temporary loss of hearing at a particular frequency as a result of exposure to sound over time. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time. |
| Threshold | The threshold generally represents the lowest signal level an animal will detect in some statistically predetermined percent of presentations of a signal. |
| Unweighted sound level | Sound levels which are 'raw' or have not been adjusted in any way, for example to account for the hearing ability of a species. |
| Weighted sound level | A sound level which has been adjusted with respect to a 'weighting envelope' in the frequency domain, typically to make an unweighted level relevant to a particular species. The overall sound level has been adjusted to account for the hearing ability of marine mammals. |

# Acronyms

| Acronym | Definition |
|---|---|
| DCO | Development Consent Order |
| EIA | Environmental Impact Assessment |
| EIA Report | Environmental Impact Assessment Report (note that the new EIA Directive refers to an EIA Report and not an Environmental Statement) |
| MMMP | Marine Mammal Mitigation Plan |
| MU | Management Unit |
| NPS | National Policy Statement |
| NSIP | Nationally Significant Infrastructure Project |
| PEIR | Preliminary Environmental Information Report |
| PINS | Planning Inspectorate |

| Acronym | Definition |
|---|---|
| PTS | Permanent Threshold Shift |
| SCANS | Small Cetaceans in European Atlantic waters and the North Sea |
| SMA | Seal Management Area |
| TCE | The Crown Estate |
| TTS | Temporary Threshold Shift |
| UXO | Unexploded Ordinance |
| VMP | Vessel Management Plan |
| WTG | Wind Turbine Generator |

# Units

| Unit | Definition |
|---|---|
| GW | Gigawatt (power) |
| kV | Kilovolt (electrical potential) |
| kW | Kilowatt (power) |
| dB | Decibel (sound pressure) |
| Hz | Hertz (frequency) |
| kHz | Kilohertz (frequency) |
| kJ | Kilojoule (energy) |
| km | Kilometres (distance) |
| $km^2$ | Kilometres squared (area) |
| knot | Knot (speed, at sea) |
| m | Metres (distance) |
| m/s | Metres per second (speed) |
| μPa | Micropascal (pressure) |

## 4.1 Introduction

4.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the results to date of the Environmental Impact Assessment (EIA) for the potential impacts of the Hornsea Project Four offshore wind farm (hereafter Hornsea Four) on marine mammals. Specifically, this chapter considers the potential impact of Hornsea Four seaward of Mean High Water Springs (MHWS) during its construction, operation and maintenance, and decommissioning phases.

4.1.1.2 Orsted Hornsea Project Four Limited (the Applicant) is proposing to develop Hornsea Four. Hornsea Four will be located approximately 65 km from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone please see **Volume 1, Chapter 1: Introduction** for further details on the Hornsea Zone). Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume 1, Chapter 4: Project Description** for full details on the Project Design).

4.1.1.3 This chapter summarises information contained within technical reports, which are included at **Volume 5, Annex 4.1: Marine Mammal Technical Report** and **Volume 4, Annex 4.5: Subsea Noise Technical Report**. The Marine Mammal Technical Report provides a detailed characterisation of the Hornsea Four marine mammal study area and the wider management units, based on existing literature sources and survey data from across the former Hornsea Zone, including the Hornsea Four array area and offshore cable corridor, and includes information on marine mammal species of ecological importance and of commercial and conservation value. The Subsea Noise Technical Report provides detailed methodologies in relation to the subsea noise modelling and presents the results of this modelling.

## 4.2 Purpose

4.2.1.1 The primary purpose of the Environmental Statement is to support the Development Consent Order (DCO) application for Hornsea Four under the Planning Act 2008 (the 2008 Act). This PEIR constitutes the Preliminary Environmental Information for Hornsea Four and sets out the findings of the EIA to date to support pre-application consultation activities required under the 2008 Act.

4.2.1.2 The EIA will be finalised following completion of pre-application consultation and the Final Environmental Statement will accompany the application to the Planning Inspectorate (PINS) for Development Consent.

4.2.1.3 This PEIR chapter:

- Presents the existing environmental baseline established from desk studies, site-specific surveys and consultation;

- Presents the potential environmental effects on marine mammals arising from Hornsea Four, based on the information gathered and the analysis and assessments undertaken to date;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental effects identified in the EIA process.

## 4.3 Planning and Policy Context

4.3.1.1 This section outlines the legislation, policy and guidance that is relevant to the assessment of the potential impacts on marine mammals associated with the construction, operation and maintenance (O&M) and decommissioning of Hornsea Four. In addition, other national, regional and local policies are considered within this assessment where they are judged to be relevant. A summary of relevant legislation and policy most relevant to this assessment is described in the following paragraphs.

4.3.1.2 All cetaceans in Northern European waters are listed under Annex IV of the EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive) as European Protected Species (EPS) of Community Interest and in need of strict protection. The harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) have protection under Annex II as species of Community Interest whose conservation requires the designation of Special Areas of Conservation (SACs).

4.3.1.3 The Habitats Directive is transposed through the Conservation of Habitats and Species Regulations 2010 (in relation to reserved matters) and the 1994 Regulations. The Conservation (Natural Habitats, &c.) Regulations (1994, as amended in 2007) implement the Habitats Directives in territorial waters out to 12 nautical miles (nm). The Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007 (as amended) (the Offshore Marine Regulations) transpose the provisions of the Habitats Directive in offshore waters, beyond 12 nm. The Habitat Regulations provide protection for designated sites, known as Natura 2000 sites which include SACs and Special Protection Areas (SPAs).

### 4.3.2 European Protected Species

4.3.2.1 The Habitats Regulations and the Offshore Marine Regulations make it an offence to injure or disturb any EPS. Any incidence of disturbance would be considered an offence if the disturbance is likely to have an ecologically significant adverse effect on a significant number of animals (note: 'adversely affect(ed)' should be taken to mean 'significantly affect the ability to survive, breed, or rear or nurture their young'). The second element is that the disturbance must be likely to significantly affect the local distribution or abundance of the species. A disturbance offence would be committed if either of these elements occurred.

4.3.2.2 If the risk of injury or significant disturbance cannot be reduced to negligible levels with mitigation, then an EPS licence is required. In England, offshore EPS licencing is managed by Natural England (NE). Licenses are granted if:

- the reason for the license relates to one of the specified purposes listed in Regulation 53(2)(e) of the Conservation (Natural Habitats) Regulations 2010;
- there is no satisfactory alternative way to reduce injury or disturbance risk (Regulation 53(9)(a)); and
- the action authorised must not be detrimental to the maintenance of the population of the species concerned at a Favourable Conservation Status (FCS) in their natural range (Regulation 53(9)(b)).

### 4.3.3 Special Areas of Conservation

4.3.3.1 In order to conserve biodiversity, by maintaining or restoring Annex II species to an FCS, the Habitats Directive requires the designation of SACs for the harbour porpoise, bottlenose dolphins the harbour seal and the grey seal.

*Harbour Porpoise*

4.3.3.2 The Hornsea Four array area is located entirely within the northern summer part of the Southern North Sea (SNS) SAC designated for harbour porpoise, for which conservation objectives and advice on activities were published in March 2019 (JNCC and Natural England 2019). Full consideration of the potential impact on the draft conservation objectives of the SNS SCI SAC will be presented as part of the Report to Inform Appropriate Assessment (RIAA) (**Volume B2, Chapter 2**).

*Harbour Seals*

4.3.3.3 The closest harbour seal SAC to Hornsea Four is The Wash and North Norfolk Coast SAC where harbour seals are listed as the primary reason for site selection. The Wash and North Norfolk Coast SAC supports the largest breeding colony of harbour seals in the UK. The boundary of The Wash and North Norfolk Coast SAC is approximately a minimum distance of 90 km from the boundary of the Hornsea Four array area and ~100 km from the ECC. Full consideration of the potential impact on the conservation objectives of the SAC will be presented as part of the RIAA (**Volume B2, Chapter 2**).

*Grey Seals*

4.3.3.4 The closest grey seal SAC to Hornsea Four is the Humber Estuary SAC where grey seals are listed as a qualifying feature but not the primary reason for site selection. The Humber Estuary SAC is approximately 75 km from the boundary of the Hornsea Four array area and approximately 50 km from the offshore ECC. To the north of that is the Berwickshire and North Northumberland Coast SAC where grey seals are listed as the primary reason for site selection. The boundary of the Berwickshire and North Northumberland Coast SAC is approximately 200 km from the boundary of the Hornsea Four array area. Full consideration of the potential impact on the conservation objectives of the SACs will be presented as part of the RIAA (**Volume B2, Chapter 2**).

#### 4.3.4 Bonn Convention

4.3.4.1 The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) requires signatories to conserve migratory species and their habitats by providing strict protection for endangered migratory species (Appendix I of the Convention) and lists migratory species which would benefit from multilateral Agreements for conservation and management (Appendix II). There are 16 cetacean species listed under Appendix I of the Bonn Convention. The UK ratified the Convention in 1985. The legal requirement for the strict protection of Appendix I species is provided by the Wildlife and Countryside Act (1981 as amended).

#### 4.3.5 Bern Convention

4.3.5.1 The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention) aims to ensure conservation and protection of wild plant and animal species and their natural habitats (listed in Appendices I and II of the Convention). There are 19 species of cetacean listed under Annex II of the Bern Convention (strictly protected fauna), including harbour porpoise, bottlenose dolphins, common dolphins, Risso's dolphins, white-beaked dolphins and minke whales. All other cetacean species as well as both grey and harbour seals are listed under Annex III of the Bern Convention (protected fauna). The obligations of the Convention are transposed into national law by means of the Wildlife and Countryside Act (1981 as amended).

#### 4.3.6 Wildlife and Countryside Act, 1981

4.3.6.1 The Wildlife and Countryside Act, 1981 makes it an offence to intentionally (or recklessly) kill, injure or take any wild animal listed on Schedule 5 of the Act, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places. All cetacean species are protected within the 12 nm territorial waters under Schedule 5 of the Wildlife and Countryside Act.

#### 4.3.7 Conservation of Seals Act, 1970

4.3.7.1 Both grey and harbour seal species are protected under the Conservation of Seals Act (1970) which provides closed seasons during which it is an offence to take or kill any seal except under licence. Following the Phocine Distemper Virus (PDV) outbreak in 1999, an Order was issued under the Conservation of Seals Act providing year-round protection to both grey and harbour seals on the east and south-east coast of England, from Berwick to Newhaven (under the Conservation of Seals (England) Order 1999).

### 4.3.8 UK Biodiversity Action Plan and the UK Post-2010 Biodiversity Framework (2012)

4.3.8.1 The UK Biodiversity Action Plan (UK BAP) was published in 1994 as a response to the 1992 Rio de Janeiro Convention on Biological Diversity. The UK BAP identifies biological resources in the UK and plans for their conservation. This was succeeded by the UK Post-2010 Biodiversity Framework in 2012 in response to the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011-2020 (published in 2010) and the EU Biodiversity Strategy (published in 2011). The UK Post-2010 Biodiversity Framework describes how the UK can meet the Aichi Biodiversity Targets. The UK BAP identified priority species that are the most threatened and require conservation. These UK BAP priority species include the cetacean and seal species present in UK waters. This list of priority species is still used to inform statutory lists of priority species in the UK.

### 4.3.9 National Policy Statements

4.3.9.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to marine mammals, is contained in the Overarching National Policy Statement (NPS) for Energy (EN-1; DECC, 2011a) and the NPS for Renewable Energy Infrastructure (EN-3, DECC, 2011b).

4.3.9.2 NPS EN-1 and NPS EN-3 include guidance on what matters are to be considered in the assessment. These are summarised in **Table 4.1** below.

**Table 4.1: Summary of NPS EN-1 and EN-3 provision relevant to marine mammals.**

| Summary of NPS EN-1 and EN-3 provisions | How and where considered in the PEIR |
|---|---|
| *Biodiversity* | |
| "*Applicants should ensure that the Environmental Statement clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity*" (paragraph 5.3.3 of NPS EN-1). | The potential effects of the construction, operation and decommissioning phases of Hornsea Four on marine mammals have been assessed in the impact assessment (see **Section 4.11: Impact Assessment**). The assessment of impacts on European designated sites is detailed in the RIAA (**Volume 2, Chapter 2**). |
| "*Applicants should assess the effects on the offshore ecology and biodiversity for all stages of the lifespan of the proposed offshore wind farm*" (paragraph 2.6.64 of NPS EN-3). | Construction, operation and decommissioning phases of Hornsea Four have been assessed in the impact assessment (see **Section 4.11: Impact Assessment**). |
| "*Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate*" (paragraph 2.6.65 of NPS EN-3). | Consultation with relevant statutory and non-statutory stakeholders has been carried out through the Hornsea Four Marine Mammal Evidence Plan Technical Panel (see **Table 4.3**). |

| Summary of NPS EN-1 and EN-3 provisions | How and where considered in the PEIR |
|---|---|
| *"Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farms should be referred to where appropriate"* (paragraph 2.6.66 of NPS EN-3). | Data on marine mammal usage of existing operational offshore wind farms was used to inform the sensitivity assessment for operation and maintenance phase impacts (see **Section 4.10.4** *et seq.*). |
| *"Applicants should assess the potential for the scheme to have both positive and negative effects on marine ecology and biodiversity"* (paragraph 2.6.67 of NPS EN-3). | Both the adverse and beneficial effects of Hornsea Four have been assessed (see **Section 4.11: Impact Assessment**). |
| *Marine mammals* | |
| *"Where necessary the assessment of the effects on marine mammals should include details of: likely feeding areas; known birthing areas/haul out sites; nursery grounds; known migration or commuting routes; duration of potentially disturbing activity including cumulative/in-combination effects; baseline noise levels; predicted noise levels in relation to mortality, Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS); soft-start noise levels; and operational noise"* (NPS EN-3; paragraph 2.6.92). | All of the specified marine mammal ecology details are included in this chapter. Construction and operational noise impacts and their likely effects on marine mammal behaviour and ecology has been assessed (see **Section 4.11: Impact Assessment**). This assessment also considers the cumulative impacts of Hornsea Four and other relevant plans or projects (see **Section 4.12: CEA**). |
| *"The Applicant should discuss any proposed piling activities with the relevant body. Where assessment shows that noise from offshore piling may reach noise levels likely to lead to an offence, the Applicant should look at possible alternatives or appropriate mitigation before applying for a EPS licence"* (NPS EN-3; paragraph 2.6.93). | Potential mitigation methods will be considered within the piling Marine Mammal Mitigation plan (MMMP) in order to reduce the risk of PTS to negligible levels (Co110,<br><br>**Table** 4.9). The details of the piling MMMP and potential mitigation methods have yet to be determined, however they will be agreed with Natural England. |

4.3.9.3 NPS EN-3 also highlights several factors relating to the determination of an application and in relation to mitigation. These are summarised in **Table 4.2** below.

**Table 4.2: Summary of NPS EN-3 policy on decision making relevant to marine mammals.**

| Summary of EN-3 provisions | How and where considered in the PEIR |
|---|---|
| *Biodiversity* | |
| *"The Secretary of State should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it"* (paragraph 2.6.68 of NPS EN-3). | The potential effects of the construction, operation and decommissioning phases of Hornsea Four on marine mammals have been assessed in the impact assessment (see **Section 4.11: Impact Assessment**). The assessment of impacts on European designated sites is detailed in the RIAA (**Volume B2, Chapter 2**). |
| *"The designation of an area as a Natura 2000 site does not necessarily restrict the construction or operation of offshore* | Where there is the potential for a significant effect on a Natura 2000 site designated for marine |

| Summary of EN-3 provisions | How and where considered in the PEIR |
|---|---|
| *wind farms in or near that area"* (paragraph 2.6.69 of NPS EN-3). | mammal species, this has been assessed within the RIAA (**Volume B2, Chapter 2**). |
| *"Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed"* (paragraph 2.6.70 of NPS EN-3). | This was considered when defining the ramp up for piling (ramp up details in **Table 4.13** and **Table 4.14**). In addition, a piling MMMP will be implemented during construction (see draft MMMP **F2.5: Outline Marine Mammal Mitigation Protocol**). The details of the final MMMP will be agreed once the final Project Design is known (Co110, **Table** 4.9). |
| *"Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact so that, where appropriate, adverse effects can then be mitigated and to enable further useful information to be published relevant to future projects"* (paragraph 2.6.71 of NPS EN-3). | Monitoring will be carried out in order to validate the predictions of the impact assessment (as required). The details of the monitoring will be agreed through consultation with the Statutory Nature Conservation Bodies (SNCBs) and presented in a marine mammal monitoring plan. |
| *Marine mammals* | |
| *"The Secretary of State should be satisfied that the preferred methods of construction, in particular for foundations and the foundation type are designed to reasonably minimise significant disturbance effects. The Secretary of State may refuse the application if suitable noise mitigation measures cannot be imposed by requirements to any development consent"* (paragraph 2.6.94 of NPS EN-3). | Hornsea Four has considered different foundation options, hammer energies and ramp-ups. Mitigation methods are considered within the piling MMMP (see draft MMMP **F2.5: Outline Marine Mammal Mitigation Protocol**). The details of the final MMMP will be agreed once the final Project Design is known (Co110, **Table** 4.9). |
| *"The conservation status of marine European Protected Species, and seals, are of relevance to the Secretary of State. The Secretary of State should take into account the views of the relevant statutory advisors"* (paragraph 2.6.95 of NPS EN-3). | The conservation status of EPS and seals is presented in **Volume 5, Annex 4.1: Marine Mammal Technical Report** and **Table 4.7** and is considered within the impact assessment for each species. |
| *"Mitigation: monitoring of a mitigation area for marine mammals surrounding the piling works prior to commencement of, and during, piling activities. During construction, 24 hour working practices may be employed to reduce the total construction programme and the potential for impacts. Soft-start procedures during pile driving may be implemented to avoid significant adverse impacts"* (paragraphs 2.6.97 to 2.6.99 of NPS EN-3). | Mitigation methods are considered within the piling MMMP (see draft MMMP **F2.5: Outline Marine Mammal Mitigation Protocol**). The details of the final MMMP will be agreed once the final Project Design is known (Co110, **Table** 4.9). |

### 4.3.10 Marine Policy Statement

4.3.10.1 The Marine Policy Statement (HM Government, 2011) is the framework for preparing Marine Plans and taking decisions affecting the marine environment. The high-level objective "*Living within environmental limits*" includes the following requirements relevant to marine mammals:

- Biodiversity is protected, conserved and, where appropriate, recovered, and loss has been halted;
- Healthy marine and coastal habitats occur across their natural range and are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems; and
- Our oceans support viable populations of representative, rare, vulnerable, and valued species.

### 4.3.11 East Inshore and East Offshore Coast Marine Plans (HM Government, 2014)

4.3.11.1 These plans provide objectives and aims that are supported by detailed policies. The East Inshore Marine Plan Area covers the coastline and includes exposed sandy beaches, soft glacial till cliffs and shallow waters (includes the Humber Estuary SAC and the Wash and North Norfolk Coast SAC). The East Offshore Marine Plan Area encompasses the marine area from 12 nautical miles out to the Exclusive Economic Zone (includes the Southern North Sea SAC). The objectives that are relevant to marine mammals include:

- Objective 6: To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan Areas;
- Objective 7: To protect, conserve and, where appropriate, recover biodiversity that is in or dependent upon the East Marine Plan Areas; and
- Objective 8: To support the objectives of MPAs (and other designated sites around the coast that overlap with, or are adjacent to, the East Marine Plan Areas), individually and as part of an ecologically coherent network.

### 4.3.12 Marine Strategy Framework Directive

4.3.12.1 The Marine Strategy Framework Directive (MFSD) 2008/56/EC provides a legislative framework for an ecosystem-based approach to the management of activities which supports the sustainable use of marine goods and services. The aim of the Directive is to achieve 'Good Environmental Status' by 2020 across Europe's marine environment. The directive was implemented into UK law via the Marine Strategy Regulations 2010. Annex I of the MSFD includes the following requirements that are relevant to marine mammals:

- Biological diversity is maintained;
- The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions;

- All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity;
- Concentrations of contaminants are at levels not giving rise to pollution effects; and
- Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

## 4.4 Consultation

4.4.1.1 Consultation is a key part of the DCO application process. Consultation regarding Marine Mammals has been conducted through Evidence Plan Technical Panel meetings and the EIA scoping process (Hornsea Four, 2018). An overview of the project consultation process is presented within **Volume 1, Chapter 6: Consultation**.

4.4.1.2 A summary of the key issues raised during consultation specific to marine mammals is outlined below in **Table 4.3**, together with how these issues have been considered in the production of this PEIR.

**Table 4.3: Consultation Responses.**

| Consultee | Date, Document, Forum | Comment | Where addressed in the PEIR |
|---|---|---|---|
| PINS | November 2018, Scoping Opinion | The Inspectorate considers that significant effects could occur during operation of the wind farm array and the substations and advises that these matters must be assessed in the ES. | The following operation and maintenance phase impacts have been assessed: operational noise, vessel collisions, vessel disturbance, reduction in prey, reduction in foraging ability (see **Section 4.11: Impact Assessment**). |
| PINS | November 2018, Scoping Opinion | The ES should assess the extent to which increases in suspended sediment may affect foraging ability of relevant marine mammal species where significant effects are likely to occur. | **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes** was used to inform the impact of reduced foraging ability (see **paragraph 4.11.1.82**) and **Volume 2, Chapter 4: Fish and Shellfish Ecology** to inform reduction in prey availability (see **paragraph 4.11.1.79**). |
| PINS | November 2018, Scoping Opinion | Electro-Magnetic Fields (EMF): The Inspectorate agrees that given the nature of the Proposed Development and the referenced literature provided in the Scoping Report, significant effects are unlikely and operational EMF effects on Marine Mammals can be scoped out of the ES. | Impact scoped out (see **Table 4.8**). |

| Consultee | Date, Document, Forum | Comment | Where addressed in the PEIR |
|---|---|---|---|
| PINS | November 2018, Scoping Opinion | Disturbance of Haul-Out Sites (construction): The Inspectorate is content that there is unlikely to be significant effects from disturbance during construction to haul out sites the nearest of which is >50 km away from the proposed landfall. The Inspectorate is content that this matter can be scoped out of the ES on that basis. | Impact scoped out (see **Table 4.8**). |
| Natural England & MMO/CEFAS | November 2018, Scoping Opinion | Sensitivity to PTS: the ES should provide an assessment of low frequency noise on relevant receptors where significant effects are likely | Marine mammal sensitivity to Permanent Threshold Shift (PTS) has been fully assessed and has been informed by the latest scientific knowledge on the topic (see **paragraph 4.10.4** *et seq.*). |
| Natural England | 30 April 2019, Hornsea Four Evidence Plan Marine Mammals Technical Panel Meeting 4 | Prey availability: There needs to be a link between specific prey species and their importance for marine mammals when assessing changes in prey availability. | The key prey species for each marine mammal species has been considered in **Table 4.32**. |
| Natural England & MMO/CEFAS | 30 April 2019, Hornsea Four Evidence Plan Marine Mammals Technical Panel Meeting 4 | Natural England and MMO/CEFAS agreed that for TTS, only ranges will be presented and that TTS impacts will not be carried through to qualitative assessment. | Temporary Threshold Shift (TTS) impact ranges are presented for construction piling noise, construction non-piling noise, Unexploded Ordnance (UXO) clearance and operational noise (see **Volume 4, Annex 4.5: Subsea Noise Technical Report**). |
| The Wildlife Trusts & Natural England | February 2019, Consultee Comments on the Noise Modelling Methodology and Approach | Raised concerns regarding the use of non-impulsive thresholds before scientific information has been published to support their use. If non-impulsive thresholds are used, it should be made clear that they are shown for illustrative purposes only, and the assessment should be against the impulsive thresholds. | Published data are now available on the transition from impulsive to non-impulsive noise characteristics with distance (Hastie *et al.* 2019). This is discussed in detail in **Appendix A** and the change in signal characteristic from impulsive to non-impulsive has been considered in the assessment of PTS alongside the full impact ranges using the impulsive PTS threshold. |
| Whale & Dolphin Conservation Wildlife Trusts & | February 2019, Consultee Comments on the Noise Modelling | Activities other than development of offshore wind farms need to be considered in the Cumulative Effects Assessment (CEA): shipping, oil and gas exploration, UXO clearance, and vessel activity. | Hornsea Four considers that shipping and fisheries are part of the baseline and so are not included in the CEA (see **Volume 4, Annex 5.3: Offshore Cumulative Effects Screening**). The CEA includes impacts from: offshore |

| Consultee | Date, Document, Forum | Comment | Where addressed in the PEIR |
|---|---|---|---|
| Natural England | Methodology and Approach | | windfarm and other offshore construction, UXO clearance, operational impacts of offshore windfarms including vessel activity, and oil and gas exploration (seismic surveys) (see **Section 4.12**). |
| Whale & Dolphin Conservation Wildlife Trusts, Natural England & MMO/CEFAS | 26 June 2019, Hornsea Four Evidence Plan Marine Mammals Technical Panel Meeting 5 | All consultees agreed that the data collected and the sources being used to define the baseline characterisation for marine mammals in the vicinity of Hornsea Four are fit for the purpose of the Hornsea Four impact assessment. | Full details of the baseline characterisation are outlined in **Volume 5, Annex 4.1: Marine Mammal Technical Report**. |

## 4.5 Study area

4.5.1.1 The Hornsea Four marine mammal study area varies depending on the species, considering individual species ecology and behaviour. The marine mammal study area has been defined at two spatial scales (see **Volume 5, Annex 4.1: Marine Mammal Technical Report** for details):

- Regional Scale Study Area: provides a wider geographic context in terms of the species present and their estimated densities and abundance. The regional study area for harbour porpoise is the North Sea MU, for minke whales and white-beaked dolphins is the Celtic and Greater North Sea MU, for harbour seals is the Southeast England SMA and for grey seals is the combined Southeast and Northeast England SMAs. This scale defines the appropriate reference population for the assessment;
- Hornsea Four Study Area: includes the Hornsea Four site-specific area survey area and the former Hornsea Zone survey area to provide an indication of the local densities of each species across impact footprints.

4.5.1.2 The marine mammal study areas, reference populations and baseline densities have been agreed with all consultees (Technical Panel Meeting 5, 26 June 2019).

## 4.6 Methodology to inform baseline

### 4.6.1 Desktop Study

4.6.1.1 A desk study was undertaken to obtain information on Marine Mammals. Data were acquired within the Hornsea Four marine mammal study area through a detailed desktop review of existing studies and datasets. Agreement was reached with all consultees that the data collected and the sources used to define the baseline characterisation for marine mammals in the vicinity of Hornsea Four are fit for the purpose of the Hornsea Four impact assessment (Technical Panel Meeting 5, 26 June 2019).

4.6.1.2 The following sources of information in **Table 4.4** were consulted. Details of the methodologies, limitations and assumptions of each dataset are detailed in **Volume 5, Annex 4.1: Marine Mammal Technical Report**.

**Table 4.4: Key Sources of Marine Mammal Data.**

| Source | Summary | Coverage of Hornsea Four marine mammal study area |
|---|---|---|
| SCANS III | Hornsea Four is located in SCANS III survey block O which was surveyed by visual aerial survey in July 2017 (Hammond *et al.* 2017). | Broadscale cetacean data with a uniform density estimate for the block containing the Hornsea Four array area and offshore ECC. |
| SMRU August haul-out counts | August haul-out surveys of harbour and grey seals (SCOS, 2017). | Broadscale data with coverage of the coastline near the offshore ECC landfall. |
| SMRU grey seal pup counts | Surveys of the main UK grey seal breeding colonies annually between mid-September and late-November to estimate the numbers of pups born at the main breeding colonies (SCOS, 2017). | Broadscale data with coverage of the coastline near the Hornsea Four offshore ECC landfall. |
| SMRU seal telemetry data | 86 harbour seals tagged in the Southeast England Seal Management Area (SMA) between 2003 and 2016 at the Wash and the Thames.<br>70 grey seals tagged in the Southeast and Northeast England SMAs between 1988 and 2015 at Donna Nook, Blakeney and the Farnes. | Broadscale data with telemetry tracks within the Hornsea Four array area and offshore ECC. |
| Seal at-sea usage maps | Telemetry data from 270 grey seals and 330 harbour seals tagged in the UK were combined with haul-out count data between 1996 and 2015 to provide estimates of at-sea usage for each species (the mean number of grey or harbour seals estimated in be in the water in each grid cell at any given time) (Russell *et al.*, 2017). | Broadscale data with estimated densities within the Hornsea Four array area and offshore ECC. |
| JNCC Report 544 | Analysis of 18 years of survey data on harbour porpoise between 1994 and 2011 held in the JCP database to identify "discrete and persistent areas of high density" that might be considered important for harbour porpoise (Heinänen and Skov, 2015). | Broadscale data with estimated densities within the Hornsea Four array area and offshore ECC. |
| JCP | 38 data sources between 1994-2010 (Paxton *et al.* 2016). JCP Phase III Data Analysis Product used to extract abundance estimates averaged for summer 2007-2010 and scaled to the SCANS III estimates for user specified areas. | Broadscale data with estimated densities within the Hornsea Four array area and offshore ECC. |

| Source | Summary | Coverage of Hornsea Four marine mammal study area |
|---|---|---|
| EU seal studies | Telemetry data from various studies on grey (Brasseur *et al.* 2015, Brasseur and Kirkwood 2015, Vincent *et al.* 2017, Aarts *et al.* 2018) and harbour seals (Brasseur *et al.* 2012, Brasseur and Kirkwood 2015, Vincent *et al.* 2017) tagged in the Netherlands, France and the Wadden Sea to assess connectivity with European sites. | Broadscale data to assess connectivity between Hornsea Four and European sites. |

### 4.6.2 Site Specific Surveys

4.6.2.1 To inform the EIA, site-specific surveys were undertaken, as agreed with the statutory consultees. A summary of surveys is outlined in **Table 4.5**.

**Table 4.5: Summary of site-specific survey data.**

| Title, year and reference | Summary | Coverage of Hornsea Four development area |
|---|---|---|
| Hornsea Four aerial surveys, 2016-2018 | HiDef Digital Aerial Surveying Ltd. conducted monthly surveys between April 2016 and March 2018. | Full coverage of the Hornsea Four Agreement for Lease (AfL) area plus 4 km buffer. |
| Former Hornsea Zone surveys 2010-2013 | Monthly boat-based visual and towed acoustic surveys conducted between March 2010 and February 2013. | Coverage of the former Hornsea Zone plus 10 km buffer which included the Hornsea Four array area. |

## 4.7 Baseline environment

### 4.7.1 Existing baseline

4.7.1.1 The baseline characterisation information is detailed in **Volume 5, Annex 4.1: Marine Mammal Technical Report**. The following species of marine mammals were as identified most likely to be present at Hornsea Four and were the focus of the baseline characterisation and the impact assessment: Harbour porpoise, minke whale, white-beaked dolphin, harbour seal and grey seal. The species selected for assessment and the relevant reference population size and density values taken forward for assessment were agreed with all stakeholders (Technical Panel Meeting 5, 26 June 2019).

4.7.1.2 The Hornsea Four site-specific surveys suggested that the area is important for harbour porpoise. This is reflected by a number of other data sets describing harbour porpoise abundance and distribution of harbour porpoise in the North Sea, and the Hornsea Four array area is located within the Southern North Sea SAC designated for harbour porpoise.

4.7.1.3 The densities used in the impact assessment are based on the best available data, with consideration given to the most up to date information together with the necessary precaution applied where there is uncertainty (i.e. where density estimates vary considerably between data sources, a range of estimates will be presented in the impact assessment, with the focus being on more recently collected data sets) (**Table 4.6**). The site-specific surveys do not extend far enough to cover the entire potential behavioural impact zones for the noise impact assessment, and as such, broader scale density estimates from SCANS III were incorporated into the assessment. This approach was agreed with all stakeholders (Technical Panel Meeting 5, 26 June 2019).

**Table 4.6: Marine mammal reference populations and densities taken forward for impact assessment for Hornsea Four.**

| Species | Density Estimate | Density Source | Reference population | Reference Population size |
|---|---|---|---|---|
| Harbour porpoise | Grid cell specific density (average across array area is 1.6 porpoise/km$^2$) | Modelled surface density estimates from the boat-based acoustic surveys of former Hornsea Zone plus a 10 km buffer | North Sea MU | 345,373 (246,526–495,752) |
| | 1.74 porpoise/km$^2$ | Hornsea Four aerial surveys – average across 24 months | | |
| | 0.888 porpoise/km$^2$ | SCANS-III Block O | | |
| Minke whale | Grid cell specific density (average across array area is 0.009 whales/km$^2$) | Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus a 10 km buffer | Celtic and Greater North Sea MU | 19,680 |
| | 0.010 whales/km$^2$ | SCANS-III Block O | | |
| White-beaked dolphin | Grid cell specific density (average across array area is 0.02 dolphins/km$^2$) | Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus a 10 km buffer | Celtic and Greater North Sea MU | 39,535 |
| | 0.002 dolphins/km$^2$ | SCANS-III Block O | | |
| Harbour seal | Grid cell specific density (average across array area is 0.03 seals/km$^2$) | At-sea usage map | Southeast England SMA | 5,792 (4,739 – 7,722) |
| Grey seal | Grid cell specific density (average across array area is 0.16 seals/km$^2$) | At-sea usage map | Southeast & Northeast England SMAs | 45,894 (40,932 – 52,224) |

### 4.7.2 Predicted future baseline

4.7.2.1 It is challenging to predict the future trajectories of marine mammal populations. Some UK marine mammal populations have undergone periods of significant change in parts of their range, with a limited understanding of the driving factors responsible. For example, there is uncertainty about whether a reduction in pup mortality or an increase in fecundity that is the cause of the recent exponential growth of grey seals in the North Sea (Russell 2017). Additionally, there is no appropriate monitoring at the right temporal or spatial scales to really understand the baseline dynamics of some marine mammal populations, including all cetacean species included in this assessment.

4.7.2.2 The results of the most recent UK assessment of favourable conservation status for each marine mammal species included in the assessment are outlined in **Table 4.7**. All species apart from harbour seals are considered to have a Favourable conservation status. For harbour seals both the short and long term trends in population size were categorised as decreasing and the assessment resulted in a conclusion of the species having Bad future prospects. However, it is important to note that this assessment for harbour seals was conducted at a UK wide level, and that the population estimates for both the Southeast and Northeast England SMAs are increasing.

**Table 4.7: Favourable conservation status for each marine mammal species.**

| Species | Conservation Status | Reference |
|---|---|---|
| Harbour porpoise | Favourable | JNCC (2013a) |
| Minke whale | Favourable | DEFRA (2017) |
| White-beaked dolphin | Favourable | DEFRA (2017) |
| Harbour seal | Bad declining | JNCC (2013c) |
| Grey seal | Favourable | JNCC (2013b) |

4.7.2.3 The potential impacts of climate change on marine mammals was reviewed and synthesised by Evans and Bjørge (2013) and they concluded that this topic remains poorly understood. In the UK, changes are predicted to manifest in relation to changes in prey abundance and distribution as a result of warmer sea temperatures. The authors also conclude that species likely to be most affected in the future will be those that have relatively narrow habitat requirements and that shelf sea species like the harbour porpoise, white-beaked dolphin and minke whale may come under increased pressure with reduced available habitat, if they experience range shifts northwards. Although the main cause of widespread declines in UK harbour seal population is not known, the prevalence of domoic acid derived from toxic algae may be a contributory factor, and could be exacerbated by increased sea temperatures (Evans and Bjørge 2013). In addition, sea level rise and an increase in storm frequency and associated wave surges could affect the availability of haul out sites for seals and increased storm frequency and associated conditions could also lead to increased pup and calf mortality (Prime 1985, Gazo *et al.* 2000, Lea *et al.* 2009).

### 4.7.3 Data Limitations

4.7.3.1 The key data limitations with the baseline data and their ability to materially influence the outcome of the EIA are the high spatial and temporal variation in marine mammal abundance and distribution in any particular area of the sea. **Volume 5, Annex 4.1: Marine Mammal**

Technical Report details the data sources used in the assessment and their associated assumptions and limitations.

## 4.8 Project basis for assessment

### 4.8.1 Impact register and impacts "scoped out"

4.8.1.1 Upon consideration of the baseline environment, the project description outlined in Volume 1, Chapter 4: Project Description and in Volume 4, Annex 5.2: Commitments Register, a number of impacts are proposed to be "scoped out" of the PEIR assessment for marine mammals. These impacts are outlined, together with a justification for scoping them out, in Table 4.8. Further detail is provided in Volume 4, Annex 5.1: Impacts Register.

**Table 4.8: Marine mammal impact register - Impacts scoped out of assessment and justification.**

| Project activity and impact | Likely significance of effect | Approach to assessment | Justification |
|---|---|---|---|
| Construction /Operation/ Decommissioning phases: Toxic Contamination (MM-C-8, MM-O-18 and MD-D-27). | No likely significant effect | Scoped Out | A commitment has been made to a Marine Pollution Contingency Plan (MPCP) which will include measures to be adopted for the prevention of pollution events and outline an emergency plan to be implemented in the unlikely event of any pollution events (see Co111 of Volume 4, Annex 5.2 Commitments Register). The MPCP will be required by a condition of the dMLs. |
| Construction phase: Disturbance to seal haul-outs at landfall (MM-C-10). | No likely significant effect | Scoped Out | There are no grey or harbour seal haul-outs sites in the vicinity of the land-fall site based on the SMRU August haul-out count surveys, and there is no evidence from the at-sea and total usage maps or the available telemetry data that harbour seals use the landfall area in any significant numbers (see Volume 5, Annex 4.1: Marine Mammal Technical Report). |
| Operation phase: EMF (MM-O-19). | No likely significant effect | Scoped Out | Based on the data available to date, there is no evidence of electromagnetic fields (EMF) related to marine renewable devices having any impact (either positive or negative) on marine mammals (Copping 2018). |

**Notes:**
Grey – Potential impact is scoped out and both PINS and Hornsea Four agree.

### 4.8.2 Commitments

4.8.2.1 Hornsea Four has made several Commitments (primary design principles inherent as part of the project, installation techniques and engineering designs/modifications as part of their pre-application phase, to avoid a number of impacts or reduce impacts as far as possible). Further Commitments (adoption of best practice guidance) are also embedded as an inherent aspect of the EIA process. The commitments adopted by Hornsea Four in relation to marine mammals are presented in

4.8.2.2

4.8.2.3 Table 4.9. Full details of commitments are included within the **Volume 4, Annex 5.2: Commitments Register**.

**Table 4.9: Relevant Marine Mammal Commitments.**

| Commitment ID | Measure Proposed | How the measure will be secured |
|---|---|---|
| Co85 | Primary: No more than two number of foundations to be installed simultaneously. | DCO Schedule 11, Part 2 - Condition 12(1)(g) and;<br>DCO Schedule 12, Part 2 - Condition 12(1)(g) (Marine mammal mitigation protocol) |
| Co108 | Tertiary: A Vessel Management Plan (VMP) will be developed pre-construction which will determine vessel routing to and from construction areas and ports to minimise encounters with marine mammals. | DCO Schedule 11, Part 2 - Condition 12(1)(d)(v) and;<br>DCO Schedule 12, Part 2 - Condition 12(1)(d)(v) (Vessel management plan) |
| Co110 | Tertiary: A piling Marine Mammal Mitigation Protocol (MMMP), will be implemented during construction and will be developed in accordance with JNCC (2010) guidance. The piling MMMP will include details of soft starts to be used during piling operations with lower hammer energies used at the beginning of the piling sequence before increasing energies to the higher levels. | DCO Schedule 11, Part 2 - Condition 12(1)(g) and;<br>DCO Schedule 12, Part 2 - Condition 12(1)(g) (Marine mammal mitigation protocol) |
| Co111 | Tertiary: A Marine Pollution Contingency Plan (MPCP) will be developed. This MPCP will outline procedures to protect personnel working and to safeguard the marine environment and mitigation measures in the event of an accidental pollution event arising from offshore operations relating to Hornsea Four. The MPCP will also include relevant key emergency contact details | DCO Schedule 11, Part 2 - Condition 12(1)(d)(i) and;<br>DCO Schedule 12, Part 2 - Condition 12(1)(d)(i) (Marine pollution contingency plan) |
| Co113 | Tertiary: A Decommissioning Marine Mammal Mitigation Protocol (MMMP), will be implemented during decommissioning. The Decommissioning MMMP will include measures to ensure the risk of permanent threshold shift (PTS) to marine mammals is negligible and will be in line with the latest relevant available guidance. | A separate Marine License will be applied for at the point of decommissioning which will include conditions relevant to minimising impacts on |

| Commitment ID | Measure Proposed | How the measure will be secured |
|---|---|---|
| | | marine mammals where appropriate. |
| Co181 | Tertiary: An Offshore Decommissioning Plan will be developed prior to decommissioning. | DCO Schedule 11, Part 1(6) and;<br>DCO Schedule 12, Part 1(6) (General Provisions) |

## 4.9 Maximum Design Scenario

4.9.1.1 The maximum design scenario (MDS) for marine mammals is outlined in **Table 4.10**.

**Table 4.10: Maximum design scenario for impacts on marine mammals.**

| Impact and Phase | Embedded Mitigation Measures | Maximum Design Scenario | Justification |
|---|---|---|---|
| *Construction* | | | |
| PTS and Disturbance from piling noise (MM-C-1). | Tertiary: Co110 | **Array Area (spatial MDS):**<br>• 180 WTGs on monopile foundations<br>• 3 offshore converter substations on monopile foundations<br>• 6 offshore transformer substations on monopile foundations<br>• 1 offshore accommodation platform on a monopile foundation<br>• Maximum design (~30% of WTG): 5,000 kJ hammer energy, 4 hours piling duration, 30 min ramp up<br>• Most likely (~70% of WTG): 4,000 kJ hammer energy, 127.5 min piling duration, 52.5 min ramp up<br>• Total WTG piling days: 216 assuming 1.2 days per monopile (151 days at most likely energy and 65 days at maximum design) over a 12 month piling period<br><br>**Array Area (temporal MDS):**<br>• 180 WTGs on pin-piled jacket foundations, 3 piles per jacket (540 total)<br>• 3 offshore converter substations on pin-piled jacket foundations (16 piles per structure (48 total), hammer energy: 2,500 kJ)<br>• 6 offshore transformer substations on pin-piled jacket foundations (24 piles per structure (144 total), hammer energy: 2,500 kJ)<br>• 1 offshore accommodation platform on a pin-piled jacket foundation (24 piles, hammer energy: 2,500 kJ)<br>• Maximum design (~30% of WTG): 2,500 kJ hammer energy, 4 hours piling duration, 30 min ramp up<br>• Most likely (~70% of WTG): 1,750 kJ hammer energy, 127.5 min piling duration, 52.5 min ramp up<br>• Total WTG piling days: 270 assuming 1.5 days per jacket foundation (189 days at most likely energy and 81 days at maximum design) over a 12 month piling period | The piling scenario with the largest PTS impact ranges represent the maximum design scenario. This differs between species depending on the frequency characteristics emitted during installation of each pile type and the hearing of the species (e.g. for high frequency cetaceans such as harbour porpoise, pin piles have a larger PTS impact range whereas for low frequency cetaceans, monopiles have a larger PTS impact range).<br><br>The maximum number of piled foundations would represent the temporal maximum design scenario for disturbance. The maximum predicted impact range for underwater noise for piled foundations would represent the spatial maximum design scenario for disturbance. |

| Impact and Phase | Embedded Mitigation Measures | Maximum Design Scenario | Justification |
|---|---|---|---|
| | | **HVAC Area of Search (spatial MDS):**<br>• 3 HVAC booster stations on monopile foundations<br>• Maximum design: 5,000 kJ hammer energy, 4 hours piling duration, 30 min ramp up<br>• Most likely: 4,000 kJ hammer energy, 127.5 min piling duration, 52.5 min ramp up<br>• Total piling days: 3.6 assuming 1.2 days per monopile over a 12-month piling period<br><br>**HVAC Area of Search (temporal MDS):**<br>• 3 HVAC booster stations on pin-piled jacket foundations (24 piles per structure (72 total), hammer energy: 2,500 kJ)<br>• Maximum design: 2,500 kJ hammer energy, 4 hours piling duration, 30 min ramp up<br>• Most likely: 1,750 kJ hammer energy, 127.5 min piling duration, 52.5 min ramp up<br>• Total piling days: 4.5 assuming 1.5 days per jacket foundation over a 12-month piling period | |
| Vessel collision risk and Disturbance from vessels (MM-C-4). | Tertiary: Co108 | **Wind Turbine Foundation Installation:**<br>• 4 installation vessels (90 return trips)<br>• 16 support vessels (360 return trips)<br>• 40 Transport / Feeder vessels (incl. Tugs) (360 return trips)<br>• Duration: 12 months<br><br>**Wind Turbine Installation:**<br>• 2 installation vessels (90 return trips)<br>• 12 Support vessels (270 return trips)<br>• 24 transport (540 return trips)<br>• Duration: 24 months<br><br>**Substation Foundation Installation (all offshore substations and accommodation platform):**<br>• 2 installation vessels (24 return trips)<br>• 12 Support vessels (108 return trips)<br>• 4 transport (48 return trips)<br>• Duration: 12 months | The maximum numbers of vessels and associated vessel movements represents the maximum potential for collision risk and disturbance. |

| Impact and Phase | Embedded Mitigation Measures | Maximum Design Scenario | Justification |
|---|---|---|---|
| | | **Substation Installation (all offshore substations and accommodation platform):**<br>• 2 installation vessels (36 return trips)<br>• 12 Support vessels (162 return trips)<br>• 4 transport (72 return trips)<br>• Duration: 24 months<br><br>**Inter-Array and Offshore Interconnector Cables Installation:**<br>• 3 main laying vessels (204 return trips)<br>• 3 main burying vessels (204 return trips)<br>• 12 support vessels (1,080 return trips)<br>• Duration: 24 months<br><br>**Offshore Export Cables Installation:**<br>• 3 main laying vessels (96 return trips)<br>• 3 main jointing vessels (72 return trips)<br>• 3 main burying vessels (96 return trips)<br>• 15 support vessels (144 return trips)<br>• Duration: 24 months | |
| Non-piling noise (e.g. cable laying, dredging) (MM-C-5). | None | **Offshore Cables Installation:**<br>• Methods: Trenching, dredging, jetting, ploughing, mass flow excavation, vertical injection, rock cutting<br>• Total length of array cables: 600 km<br>• Total length of interconnector cables/circuits: 90 km<br>• Where possible, the export cables will be buried below the seabed through to landfall.<br>• Total length of export cables: 654 km (6 cables x 109 km cable length)<br>• Total duration of cable installation: 36 months | Maximum potential for underwater noise impacts. |
| PTS and Disturbance from UXO clearance | None | **UXO Clearance:**<br>• Estimated 2,263 targets<br>• 86 UXOs may require clearance.<br>• One UXO will be cleared every 24 hours | Estimated maximum design based on data from other projects in the Hornsea Zone. A detailed UXO survey would be completed prior to construction. The type, size (net |

| Impact and Phase | Embedded Mitigation Measures | Maximum Design Scenario | Justification |
|---|---|---|---|
| (MM-C-11, MM-C-12). | | • 86 detonations in 86 days | explosive quantities (NEQ)) and number of possible detonations and duration of UXO clearance operations is therefore not known at this stage. |
| Reduction in prey availability (MM-C-6). | None | Assessment is based on the MDS presented in **Volume 2, Chapter 4: Fish and Shellfish Ecology.** | |
| Reduction in foraging ability (MM-C-7). | None | Maximum amount of suspended sediment released during construction activities and associated duration - see **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes.** | |
| *Operation* | | | |
| Operational noise (MM-O-14). | None | **Number of Wind Turbines:**<br>• 180 (maximum rotor diameter 305 m) | The largest turbine will result in the highest levels of operational noise transmission |
| Vessel collision risk and Disturbance from vessels (MM-O-28, MM-O-15). | Tertiary: Co108 | **Vessel return trips per year:**<br>• 2,580 for wind turbine visits<br>• 780 for wind turbine foundation visits<br>• 65 for platform visits - Structural Scope<br>• 100 for platform visits - Electrical Scope<br>• 260 crew shift transfer<br>• 124 jack-up visits<br>• 1,205 crew vessel wind turbine visits<br>• 104 supply vessel visits to accommodation platform | The maximum numbers of vessels and associated vessel movements represents the maximum potential for collision risk and disturbance. |
| Reduction in prey availability (MM-O-16). | None | Maximum effect on fish prey species as detailed in the assessment in **Volume 2, Chapter 4: Fish and Shellfish Ecology.** | |
| Reduction in foraging ability (MM-O-17). | None | Maximum amount of suspended sediment released during construction activities and associated duration - see **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes.** | |

| | | |
|---|---|---|
| *Decommissioning* | | |
| PTS and Disturbance from underwater noise (MM-O-20). | Tertiary: Co113 | Maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures. This is much less than pile driving and therefore impacts would be less than as assessed during the construction phase/ Piled foundations would likely be cut approximately 1 m below the seabed. |
| Vessel collision risk and Disturbance from vessels (MM-D-23, MM-D-24). | Tertiary: Co108 | Assumed to be similar vessel types, numbers and movements to construction phase (or less). |
| Reduction in prey availability (MM-D-25). | None | Dependant on results of **Volume 2, Chapter 4: Fish and Shellfish Ecology**. |
| Reduction in foraging ability (MM-D-26). | None | Maximum amount of suspended sediment released during decommissioning activities and associated duration - see **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**. |

## 4.10 Assessment methodology

4.10.1.1 The assessment methodology for marine mammals is consistent with that presented in Annex C of the Hornsea Four Scoping Report (Ørsted, 2018). The consultees were provided with an outline of the Noise Modelling Methodology and Approach document (February 2019) and all subsequent consultee comments were incorporated into the assessment methodology as appropriate.

### 4.10.2 Impact assessment criteria

4.10.2.1 The criteria for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and then predicting the magnitude of the impacts in line with the methodology set out in **Volume 1, Chapter 5: Environmental Impact Assessment Methodology**. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The criteria for defining marine mammal sensitivity in this chapter are outlined in **Table 4.11** below.

**Table 4.11: Definition of terms relating to receptor sensitivity.**

| Sensitivity | Definition used in this chapter |
|---|---|
| Very High | No ability to adapt behaviour so that survival and reproduction rates are affected.<br>No tolerance – Effect will cause a change in both reproduction and survival rates.<br>No ability for the animal to recover from the effect. |
| High | Limited ability to adapt behaviour so that survival and reproduction rates may be affected.<br>Limited tolerance – Effect may cause a change in both reproduction and survival of individuals.<br>Limited ability for the animal to recover from the effect. |
| Medium | Ability to adapt behaviour so that reproduction rates may be affected but survival rates not likely to be affected.<br>Some tolerance – Effect unlikely to cause a change in both reproduction and survival rates.<br>Ability for the animal to recover from the effect. |
| Low | Receptor is able to adapt behaviour so that survival and reproduction rates are not affected.<br>Receptor is able to tolerate the effect without any impact on reproduction and survival rates.<br>Receptor is able to return to previous behavioural states/activities once the impact has ceased. |

4.10.2.2 The criteria for defining magnitude in this chapter are outlined in **Table 4.12** below.

**Table 4.12: Definition of terms relating to magnitude of an impact.**

| Magnitude of impact | Definition used in this chapter |
|---|---|
| Major | The impact would affect the behaviour and distribution of sufficient numbers of individuals, with sufficient severity, to affect the favourable conservation status and/or the long-term viability of the population at a generational scale (Adverse). |
| | Long term, large scale increase in the population trajectory at a generational scale (Beneficial). |
| Moderate | Temporary changes in behaviour and/or distribution of individuals at a scale that would result in potential reductions to lifetime reproductive success to some individuals although not |

| Magnitude of impact | Definition used in this chapter |
|---|---|
| | enough to affect the population trajectory over a generational scale. Permanent effects on individuals that may influence individual survival but not at a level that would alter population trajectory over a generational scale (Adverse). |
| | Benefit to the habitat influencing foraging efficiency resulting in increased reproductive potential and increased population health and size (Beneficial). |
| Minor | Short-term and/or intermittent and temporary behavioural effects in a small proportion of the population. Reproductive rates of individuals may be impacted in the short term (over a limited number of breeding cycles). Survival and reproductive rates very unlikely to be impacted to the extent that the population trajectory would be altered (Adverse). |
| | Short term (over a limited number of breeding cycles) benefit to the habitat influencing foraging efficiency resulting in increased reproductive potential (Beneficial). |
| Negligible | Very short term, recoverable effect on the behaviour and/or distribution in a very small proportion of the population. No potential for the any changes in the individual reproductive success or survival therefore no changes to the population size or trajectory (Adverse). |
| | Very minor benefit to the habitat influencing foraging efficiency of a limited number of individuals (Beneficial). |

4.10.2.3 The significance of the effect upon marine mammals is determined by a matrix combining the magnitude of the impact and the sensitivity of the receptor. The method employed for this assessment is presented in **Figure 4.1**. Where a range of significance of effect is presented in **Figure 4.1**, the final assessment for each effect is based upon expert judgement. For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

| | | Magnitude of Impact/Degree of Change | | | |
|---|---|---|---|---|---|
| | | **Negligible** | **Minor** | **Moderate** | **Major** |
| Value, Importance, Sensitivity | Low | Not Significant | Not Significant or Minor (Not Significant) | Minor (Not Significant) | Minor (Not Significant) or Moderate (Significant) |
| | Medium | Not Significant | Minor (Not Significant) | Moderate (Significant) | Moderate (Significant) or Major (Significant) |
| | High | Not Significant | Minor (Not Significant) or Moderate (Significant) | Moderate (Significant) or Major (Significant) | Major (Significant) or Substantial (Significant) |
| | Very High | Not Significant | Moderate (Significant) or Major (Significant) | Major (Significant) or Substantial (Significant) | Substantial (Significant) |

**Figure 4.1: Deriving the Level of Significance of an Impact.**

4.10.2.4 Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the interest features of internationally designated sites as described within **Section 4.3.3** of this chapter (with the assessment on the site itself deferred to the RIAA for Hornsea Four, **Volume B2, Chapter 2**).

4.10.2.5 The RIAA Report has been prepared in accordance with PINS Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (PINS, 2016) and will be submitted as part of the application for Development Consent (**Volume B2, Chapter 2**). Hornsea Four has also consulted specifically on HRA through the EP process, in line with the Planning Inspectorate's Advice Note 10: HRA (January 2017). Hornsea Four submitted the Habitats Regulations Assessment (HRA) Screening Report for consultation on the 08 October 2018. At the request of Natural England, additional sites were "screened in" to the HRA and the report updated and issued on 18 June 2019. The Draft RIAA will be made available shortly after the PEIR for consultation with the statutory nature conservation bodies (SNCBs) and other potentially affected transboundary consultees and interested parties. The consultation period for the RIAA concludes on 23 September 2019, aligned with the S42 consultation on the PEIR. This on-going dialogue with the nature conservation bodies will continue throughout the EP process as the RIAA is progressed.

### 4.10.3 Approach to underwater noise assessment

*Noise modelling*

4.10.3.1 The noise levels likely to occur as a result of the construction of Hornsea Four were predicted by Subacoustech Environmental Ltd using their INSPIRE model. A detailed description of the modelling approach is presented in the **Volume 4, Annex 4.5: Subsea Noise Technical Report**. Modelling was undertaken at four representative locations, three within the Hornsea Four array area (northwest, seal and south) and the accompanying HVAC booster station search area (see **Volume 4, Annex 4.5: Subsea Noise Technical Report** for details and maps).

4.10.3.2 Recent industry operational experience when installing offshore wind farms has shown that the actual hammer energies used during construction have been much lower than those maximum design scenario parameters defined during the assessments. In recognition of this, a most likely ramp up scenario is defined to be representative of the majority of the piling activity. In this chapter, the main assessment is based upon the most likely scenario as it is more representative of the actual piling activity likely to be used during the majority of piling events (~70% of WTG (NOTE: The 70% is indicative at this stage and is based on Orsted piling experience at a number of offshore wind farms including Westermost Rough, Burbo Bank Extension, Race Bank, Anholt, Bokrum Riffgrund and Gode Wind)). The most-likely scenario based on engineering predictions is a maximum of 4,000 kJ hammer energy for monopiles and 1,750 kJ for pin piles (**Table 4.13**). The most likely piling source levels for each modelling location are detailed in **Table 4.15**.

4.10.3.3 In addition to this, the maximum design scenario is presented for each species at the modelling location which was identified to have the maximum impact on each species, in terms of the number of animals predicted to be impacted. The maximum design scenario is intended to cover the absolute maximum piling parameters that would ever be required to install a foundation (in terms of maximal hammer energies and longest piling durations), and, based on ground investigation work, it is expected that this will only be required at ~30% of the WTG locations (NOTE: The 30% is indicative at this stage and will be updated for the ES and DCO). The maximum design scenario based on engineering predictions is 5,000 kJ hammer energy for monopiles and 2,500 kJ for pin piles (**Table 4.14**). The maximum design piling source levels for each modelling locations are detailed in **Table 4.15**. Between PEIR and ES submission, there will be a refinement to the maximum design ramp up profile. It is anticipated that the refinement of the ramp-up procedure will be such that predicted impacts presented in the final ES chapter will be equal to, or potentially less than the maximum design presented in **Table 4.17**.

**Table 4.13: Hornsea Four piling most likely scenario ramp up.**

| % of maximum hammer capacity | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|
| Monopile blow energy (kJ) | 800 | 1,600 | 2,400 | 3,200 | 4,000 |
| Pin pile blow energy (kJ) | 350 | 700 | 1,050 | 1,400 | 1,750 |
| Number of strikes | 3 | 75 | 112 | 113 | 2,250 |
| Strike Rate (strikes/min) | 1 | 10 | 15 | 15 | 30 |
| Duration | 30 mins | 7.5 mins | 7.5 mins | 7.5 mins | 75 mins |

**Table 4.14: Hornsea Four maximum design scenario ramp up.**

| % of maximum hammer capacity | 20% | 40% | 60% | 80% | 100% |
|---|---|---|---|---|---|
| Monopile blow energy (kJ) | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 |
| Pin pile blow energy (kJ) | 500 | 1,000 | 1,500 | 2,000 | 2,500 |
| Strike Rate (strikes/min) | 10 | 10 | 15 | 15 | 30 |
| Duration | 7.5 mins | 7.5 mins | 7.5 mins | 7.5 mins | 210 mins |

**Table 4.15: Hornsea Four piling noise source levels ($SPL_{peak}$ dB re 1 μPa @ 1 m, $SEL_{ss}$ dB re 1 μPa2s @ 1 m).**

| Most Likely | Monopile (4,000 kJ) | | Pin pile (1,750 kJ) | |
|---|---|---|---|---|
| | $SPL_{peak}$ | $SEL_{ss}$ | $SPL_{peak}$ | $SEL_{ss}$ |
| NW | 244.0 | 218.0 | 240.2 | 214.2 |
| E | 243.4 | 217.4 | 239.5 | 213.5 |
| S | 243.4 | 217.4 | 239.6 | 213.6 |
| HVAC | 244.0 | 218.0 | 240.2 | 214.2 |
| **Maximum Design** | **Monopile (5,000 kJ)** | | **Pin pile (2,500 kJ)** | |
| | $SPL_{peak}$ | $SEL_{ss}$ | $SPL_{peak}$ | $SEL_{ss}$ |
| NW | 244.8 | 218.8 | 242.0 | 216.0 |
| E | 244.2 | 218.2 | 241.3 | 215.3 |
| S | 244.3 | 218.3 | 241.4 | 215.4 |

| Most Likely | Monopile (4,000 kJ) | | Pin pile (1,750 kJ) | |
|---|---|---|---|---|
| | $SPL_{peak}$ | $SEL_{ss}$ | $SPL_{peak}$ | $SEL_{ss}$ |
| HVAC | 244.8 | 218.8 | 242.0 | 216.0 |

*Permanent and temporary Threshold Shift (PTS and TTS)*

4.10.3.4 For marine mammals, the main impact from Hornsea Four will be as a result of underwater noise produced during construction. Therefore, a detailed assessment has been provided for this impact pathway. Exposure to loud sounds can lead to a reduction in hearing sensitivity (a shift in hearing threshold), which is generally restricted to particular frequencies. This threshold shift results from physical injury to the auditory system and may be temporary (TTS) or permanent (PTS). The PTS and TTS onset thresholds used in this assessment are those presented in Southall *et al.* (2019). The method used to calculate PTS impact ranges for both 'instantaneous' PTS (SPLpk), and one value for PTS induced by cumulative sound exposure ($SEL_{cum}$, over 24 hours) are detailed in **Volume 4, Annex 4.5: Subsea Noise Technical Report**).

*Approach to TTS assessment*

4.10.3.5 The ranges that indicate TTS onset were modelled and are presented in this impact assessment. However, as TTS onset is defined primarily as a means of predicting PTS onset, there is currently no threshold for TTS-onset that would indicate a biologically significant amount of TTS; therefore it was impossible to carry out a quantitative assessment of the magnitude or significance of the impact of TTS on marine mammals. The current set of TTS-onset threshold would result in a significant overestimate of the impact due to the extremely large resulting impact ranges representing the smallest measurable amount of TTS. These thresholds were not used to quantify the numbers of animals at risk of any TTS.

*Approach to behavioural disturbance*

4.10.3.6 The assessment of disturbance was based on the current best practice methodology, making use of the best available scientific evidence. This incorporated the application of a species-specific dose-response approach rather than a fixed behavioural threshold approach. Noise contours at 5dB intervals were generated by noise modelling and overlain on species density surfaces to predict the number of animals potentially disturbed. This allowed for the quantification of the number of animals that potentially will respond.

4.10.3.7 The dose-response curve adopted in this assessment for all cetaceans was developed by Graham *et al.* (2017a) and was generated from data on harbour porpoises collected during the first six weeks of piling during Phase 1 of the Beatrice Offshore Wind Farm monitoring program (**Figure 4.2**). In the absence of species-specific data on white-beaked dolphins or minke whales, this dose response curve has been adopted for all cetaceans, as agreed with statutory consultees (Evidence Plan Technical Panel Meeting 1 and Evidence Plan Note: Noise Modelling Methodology and Approach, February 2019). For both species of seal, a dose response curve was derived from the data collected and analysed by Russell *et al.* (2016) on harbour seal responses during several months of pile driving at the Lincs Offshore Wind Farm (Russell and Hastie 2017) (**Figure 4.3**).

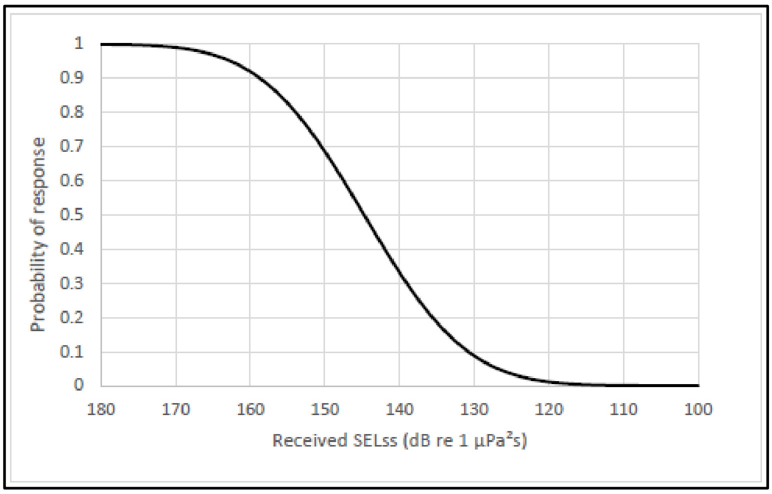


**Figure 4.2: Relationship between the proportion of animals responding and the received single strike SEL ($SEL_{ss}$), based on passive acoustic monitoring results obtained during Phase 1 of the Beatrice Offshore Wind Farm monitoring program (Graham *et al.* 2017a).**

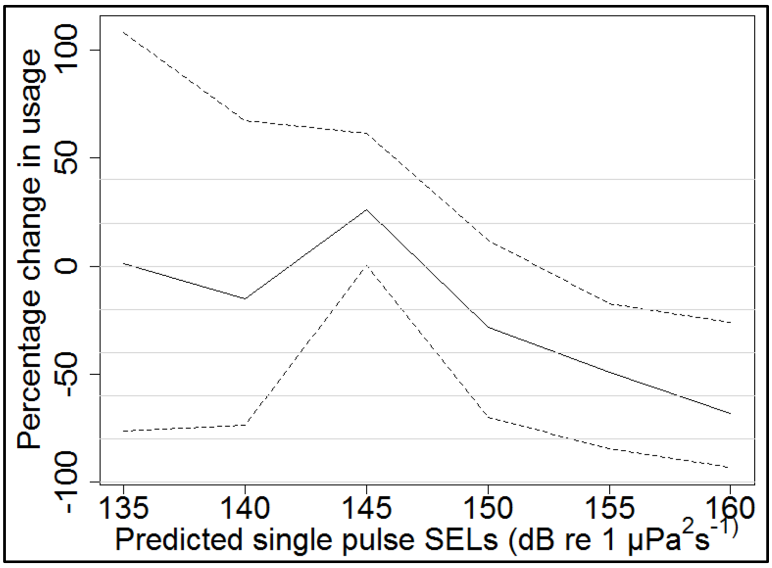


**Figure 4.3: The predicted percentage change in seal usage given $SEL_{ss}$ at 5 dB increments (Russell and Hastie 2017). Please note each increment represents the next 5 dB. E.g. the predicted percentage change in usage value at 135 dB represents the mean for cells with estimated SELs of 135 dB ≤ 140 dB.**

### 4.10.4 Marine mammal sensitivity

*Cetacean sensitivity to PTS*

4.10.4.1 The ecological consequences of PTS for marine mammals is uncertain. At a recent BEIS funded expert elicitation workshop held at the University of St Andrews (March 2018), experts in marine mammal hearing discussed the nature, extent and potential consequence of PTS to UK marine mammal species (Booth and Heinis 2018). A number of general points came out in discussions as part of the elicitation. These included that PTS did not mean animals were deaf, that the limitations of the ambient noise environment should be considered and that the magnitude and frequency band in which PTS occurs are critical to assessing the effect on vital rates.

4.10.4.2 Southall *et al.* (2007) defined the onset of temporary threshold shifts (TTS) as "*being a temporary elevation of a hearing threshold by 6 dB*" (in which the reference pressure for the dB is 1µPa). Although 6 dB of TTS is a somewhat arbitrary definition of onset, it has been adopted largely because 6 dB is a measurable quantity that is typically outside the variability of repeated thresholds measurements. The onset of PTS was defined as a non-recoverable elevation of the hearing threshold of 6 dB, for similar reasons. Based upon TTS growth rates obtained from the scientific literature, it has been assumed that the onset of PTS occurs after TTS has grown to 40 dB. The growth rate of TTS is dependent on the frequency of exposure, but is nevertheless assumed to occur as a function of an exposure that results in 40 dB of TTS, i.e. 40 dB of TTS is assumed to equate to 6 dB of PTS.

4.10.4.3 To put this magnitude of loss of sensitivity into context, in humans, hearing loss due to aging can lead to reduction in sensitivity at the highest frequency part of the hearing spectrum of ~10 dB. By age 40 this increases to 30 dB, by age 60, this can be as much as 70 dB in the highest frequencies and 30 dB in the mid frequencies. 'Mild' hearing loss in humans is defined as a loss of hearing sensitivity of 20-40 dB. Experts agreed that any threshold shifts as a result of pile driving would manifest themselves in the 2-10 kHz range (Kastelein *et al.* 2017), and that a PTS 'notch' of 6-18 dB in a narrow frequency band in the 2-10 kHz region is unlikely to significantly affect the fitness of individuals (ability to survive and reproduce).

4.10.4.4 The low frequency noise produced during piling may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. For minke whales, (Tubelli *et al.* 2012) estimated the most sensitive hearing range as the region with thresholds within 40 dB of best sensitivity, to extend from 30 to 100 Hz up to 7.5 to 25 kHz, depending on the specific model used. Therefore a 2- 0 kHz notch of 6 dB will only affect a small region of minke whale hearing. In addition, minke whale communication signals have been demonstrated to be below 2 kHz (Edds-Walton 2000, Mellinger *et al.* 2000, Gedamke *et al.* 2001, Risch *et al.* 2013, Risch *et al.* 2014). Like other mysticete whales, minke whales are also thought to be capable of hearing sounds through their skull bones (Cranford and Krysl 2015).

4.10.4.5 Although the potential for PTS resulting from exposure to pile driving noise to affect the survival and reproduction of individuals is considered low, given the current uncertainty surrounding these effects and how critical sound can be for echolocation, foraging and communication in cetaceans, all cetaceans have been assessed as having a **medium** sensitivity to PTS.

4.10.4.6 Data collected during windfarm construction have demonstrated that porpoise detections around the pile driving site decline several hours prior to the start of pile driving, and it is assumed that this is due to the increase in other construction related activities and vessel presence in advance of the actual pile driving (Brandt *et al.* 2018, Graham *et al.* 2018). Therefore, the presence of construction related vessels in the vicinity prior to the start of piling can act as a local scale deterrent for harbour porpoise and therefore reduce the risk of auditory injury. Assumptions that harbour porpoise are present in the vicinity of the pile driving at the start of the soft start are therefore likely to be overly conservative.

*Seal sensitivity to PTS*

4.10.4.7 Seals are less dependent on hearing for foraging than cetaceans, but may rely on sound for communication and predator avoidance (Deecke *et al.* 2002). Seals have very well developed tactile sensory systems that are used for foraging (Dehnhardt *et al.* 2001) and Hastie *et al.* (2015) reported that, based on calculations of SEL of tagged seals during the Lincs Offshore Windfarm construction, at least half of the tagged seals would have received a dose of sound greater than published thresholds for PTS. A recent update of this analysis using the revised Southall *et al.* (2019) thresholds and weighting reduced this proportion to 25% of the seals (G. Hastie pers comm). Based on the extent of the offshore wind farm construction in the Wash over the last ten years and the degree of overlap with the foraging ranges of harbour seals in the region (Russell *et al.* 2016), it would not be unreasonable to suggest that a large number of individuals of the Wash population may have experienced levels of sound with the potential to cause hearing loss.

4.10.4.8 The Wash harbour seal population has been increasing over this period which may provide an indication that either: a) seals are not developing PTS despite predictions of exposure that would indicate that they should; or b) that the survival and fitness of individual seals are not affected by PTS. Point a) would indicate that methods for predicting PTS are perhaps unreliable and over precautionary, and b) would suggest a lack of sensitivity to the effects of PTS. At the recent BEIS funded expert elicitation workshop (Booth and Heinis 2018) experts concluded that the probability of PTS significantly affecting the survival and reproduction of either seal species was very low. As a result of this, and the fact that seals do not generally use hearing as their primary sensory modality for finding prey and navigation, in the same way as cetaceans do, the sensitivity of seals to PTS has been assessed as **low**.

*Harbour porpoise sensitivity to pile-driving disturbance*

4.10.4.9 Previous studies have shown that harbour porpoise are displaced from the vicinity of piling events. For example, studies at wind farms in the German North Sea have recorded large declines in porpoise detections close to the piling (> 90% decline at noise levels above 170 dB) with decreasing effect with increasing distance from the pile (25% decline at noise levels between 145 and 150 dB) (Brandt *et al.* 2016). The detection rates revealed that porpoise were only displaced from the piling area in the short term (1 to 3 days) (Brandt *et al.* 2011, Dähne *et al.* 2013, Brandt *et al.* 2016, Brandt *et al.* 2018). Harbour porpoise are small cetaceans which makes them vulnerable to heat loss and requires them to maintain a high metabolic rate with little energy remaining for fat storage. This makes them vulnerable to starvation if they are unable to obtain sufficient levels of prey intake.

4.10.4.10 Studies using Digital Acoustic Recording Tags (DTAGs) have shown that porpoise tagged after capture in pound nets foraged on small prey nearly continuously during both the day and the night on their release (Wisniewska *et al.* 2016). However, Hoekendijk *et al.* (2018) point out that this could be an extreme short term response to capture in nets, and may not reflect natural harbour porpoise behaviour. Nevertheless, if the foraging efficiency of harbour porpoise is disturbed or if they are displaced from a high-quality foraging ground, and are unable to find suitable alternative feeding grounds, they could potentially be at risk of changes to their overall fitness if they are not able to compensate and obtain sufficient food intake in order to meet their metabolic demands.

4.10.4.11 The results from Wisniewska *et al.* (2016) could also suggest that porpoises have an ability to respond to short term reductions in food intake, implying a resilience to disturbance. As Hoekendijk *et al.* (2018) argue, this could help explain why porpoises are such an abundant and successful species. It is important to note that the studies providing evidence for the responsiveness of harbour porpoises to piling noise have not provided any evidence for subsequent individual consequences. In this way, responsiveness to disturbance cannot reliably be equated to sensitivity to disturbance and porpoises may well be able to compensate by moving quickly to alternative areas to feed, while at the same time increasing their feeding rates.

4.10.4.12 Monitoring of harbour porpoise activity at the Beatrice Offshore Wind Farm during pile driving activity has indicated that porpoises were displaced from the immediate vicinity of the pile driving activity – with a 50% probability of response occurring at approximately 7 km. This monitoring also indicated that the response diminished over the construction period, so that eight months into the construction phase, the range at which there was a 50% probability of response was only 1.3 km. In addition, the study indicated that porpoise activity recovered between pile driving events.

4.10.4.13 A study of tagged harbour porpoise has shown large variability between individual responses to an airgun stimulus (van Beest *et al.* 2018). Of the five porpoise tagged and exposed to airgun pulses at ranges of 420–690 m (SEL 135–147 dB re 1 $\mu Pa^2 s$), one individual showed rapid and directed movements away from the source. Two individuals displayed shorter and shallower dives immediately after exposure and the remaining two animals did not show any quantifiable response. Therefore, there is expected to be a high level of variability in responses from individual harbour porpoise exposed to low frequency broadband pulsed noise (including both airguns and pile-driving).

4.10.4.14 At a BEIS funded expert elicitation workshop held in Amsterdam in June 2018, experts in marine mammal physiology, behaviour and energetics discussed the nature, extent and potential consequences of disturbance to harbour porpoise (Booth *et al.* 2019). Experts were asked to estimate the potential consequences of a six hour period of zero energy intake, assuming that disturbance from a pile driving event resulted in missed foraging opportunities for this duration. The experts agreed that first year calf survival (post-weaning) and fertility were the most likely vital rates to be affected by disturbance, but that juvenile and adult survival were unlikely to be significantly affected as these life-stages were considered to be more robust. Experts agreed that the final third of the year was the most critical for harbour porpoise as they reach the end of the current lactation period and the start of new pregnancies, therefore it was thought that significant impacts on fertility would only occur when animals received repeated exposure throughout the whole year. Experts agreed it would likely take >300 days of repeated disturbance to an individual before there was any effect on that individual's fertility, and that it was very unlikely an animal would terminate a pregnancy early. The experts agreed that calf survival could be reduced by only a few days of repeated disturbance to a mother/calf pair during early lactation; however, there was a wide range in opinion on how many days of repeated disturbance to the same mother-calf pair would be required to reduce the calf survival to zero. This ranged between <50 days to >300 days, with the highest probability around 70-100 days of repeated disturbance; however it is highly unlikely that the same mother-calf pair would repeatedly return to the area in order to receive these levels of repeated disturbance over this many days.

4.10.4.15 Due to observed responsiveness to piling, and their income breeder life history, harbour porpoises have been assessed here as having a **medium** sensitivity to disturbance and resulting displacement from foraging grounds.

*Minke whale sensitivity to pile-driving disturbance*

4.10.4.16 There is little information available on the behavioural responses of minke whales to underwater noise. Minke whales have been shown to change their diving patterns and behavioural state in response to disturbance from whale watching vessels; and it was suggested that a reduction in foraging activity at feeding grounds could result in reduced reproductive success in this capital breeding species (Christiansen *et al.* 2013). There is only one study showing minke whale reactions to sonar signals (Sivle *et al.* 2015) with severity scores above 4 for a received SPL of 146 dB re 1 µPa (score 7) and a received SPL of 158 dB re 1 µPa (score 8). There is a study detailing minke whale responses to the Lofitech device which has a source level of 204 dB re re 1 µPa @1m, which showed minke whales within 500 m and 1,000 m of the source exhibiting a behavioural response. Estimated received level at 1,000 m was 136.1 dB re 1 µPa (McGarry *et al.* 2017).

4.10.4.17 Since minke whales are known to forage in UK waters in the summer months, there is the potential for displacement to impact on reproductive rates. Therefore, minke whales have been assessed as having a **medium** sensitivity to disturbance and resulting displacement from foraging grounds. Due to their large size and capacity for energy storage, it is expected that minke whales will be able to tolerate temporary displacement from foraging areas much better than harbour porpoise.

*White-beaked dolphin sensitivity to pile-driving disturbance*

4.10.4.18 There is a single study detailing white beaked dolphin responses to playbacks of amplitude-modulated tones and synthetic pulse-bursts; responses were observed in 90 out of 123 exposures and received levels varied between 153 and 161 dB re 1 µPa for pulse-burst signals (Rasmussen *et al.* 2016). Due to the limited information on the effects of disturbance on white-beaked dolphins, bottlenose dolphins can be used as a proxy since both species are categorised as mid-frequency cetaceans.

4.10.4.19 Bottlenose dolphins have been shown to be displaced from an area as a result of the noise produced by offshore construction activities; for example, avoidance behaviour in bottlenose dolphins has been shown in relation to dredging activities (Pirotta *et al.* 2013). In a recent study on bottlenose dolphins in the Moray Firth (in relation to the construction of the Nigg Energy Park in the Cromarty Firth), small effects of pile driving on dolphin presence have been observed, however, dolphins were not excluded from the vicinity of the piling activities (Graham *et al.* 2017b). In this study the median peak-to-peak source levels recorded during impact piling were estimated to be 240 dB re 1μPa (range 8 dB) with a single pulse source level of 198 dB re 1 $\mu Pa^2 s$. The pile driving resulted in a slight reduction of the presence, detection positive hours and the encounter duration for dolphins within the Cromarty Firth, however, this response was only significant for the encounter durations. Encounter durations decreased within the Cromarty Firth (though only by a few minutes) and increased outside of the Cromarty Firth on days of piling activity. These data highlight a small spatial and temporal scale disturbance to bottlenose dolphins as a result of impact piling activities.

4.10.4.20 There is the potential for behavioural disturbance and displacement to result in disruption in foraging and resting activities and an increase in travel and energetic costs. However, it has been previously shown that bottlenose dolphins have the ability to compensate for behavioural responses as a result of increased commercial vessel activity (New *et al.* 2013). Therefore, while there remains the potential for disturbance and displacement to affect individual behaviour and therefore vital rates and population level changes, bottlenose dolphins do have some capability to adapt their behaviour and tolerate certain levels of temporary disturbance.

4.10.4.21 By using the sensitivity of bottlenose dolphins as a proxy for white-beaked dolphins, white-beaked dolphins are assessed as having a **medium** sensitivity to disturbance.

*<u>Harbour seal sensitivity to pile-driving disturbance</u>*

4.10.4.22 A study of tagged harbour seals in the Wash has shown that they are displaced from the vicinity of piles during pile-driving activities. Russell *et al.* (2016) showed that seal abundance was significantly reduced within an area with a radius of 25 km from a pile, during piling activities, with a 19 to 83% decline in abundance during pile-driving compared to during breaks in piling. The duration of the displacement was only in the short-term as seals returned to non-piling distributions within two hours after the end of a pile-driving event. Unlike harbour porpoise, both harbour and grey seals store energy in a thick layer of blubber, which means that they are more tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Therefore, they are unlikely to be particularly sensitive to short-term displacement from foraging grounds during periods of active piling.

4.10.4.23 At the expert elicitation workshop in Amsterdam in 2018, (Booth *et al.* 2019), experts agreed the most likely potential consequences of a six hour period of zero energy intake, assuming that disturbance from pile driving resulted in missed foraging opportunities. In general, it was agreed that harbour seals were considered to have a reasonable ability to compensate for lost foraging opportunities due to their generalist diet, mobility, life history and adequate fat stores. The survival of 'weaned of the year' animals and fertility were determined to be the most sensitive life history parameters to disturbance (i.e. leading to reduced energy intake). Juvenile harbour seals are typically considered to be coastal foragers

(Booth *et al.* 2019) and so less likely to be exposed to disturbances and similarly pups were thought to be unlikely to be exposed to disturbance due to their proximity to land. Experts considered that the location of the disturbance would influence the effect of the disturbance, with a greater effect if animals were disturbed at a foraging ground as opposed to when animals were transiting through an area. It was thought that for an animal in bad condition, moderate levels of repeated disturbance might be sufficient to reduce fertility, however there was a large amount of uncertainty in this estimate, with opinions ranging between <50 days and >300 days. The 'weaned of the year' were considered to be most vulnerable following the post-weaning fast, and that during this time, experts felt it might take ~60 days of repeated disturbance before there was expected to be any effect on the probability of survival, however again, there was a lot of uncertainty surrounding this estimate with estimates ranging between <50 days and >200 days. Similarly to above, it is considered unlikely that individual harbour seals would repeatedly return to a site where they'd been previously displaced from in order to experience this number of days of repeated disturbance.

4.10.4.24 Taking the above into consideration, harbour seals have been assessed as having **medium** sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

*Grey seal sensitivity to pile-driving disturbance*

4.10.4.25 There are still limited data on grey seal behavioural responses to pile driving. The key dataset on this topic is presented in Aarts *et al.* (2018) where 20 grey seals were tagged in the Wadden Sea to record their responses to pile driving at two offshore wind farms: Luchterduinen in 2014 and Gemini in 2015. The grey seals showed varying responses to the pile driving, including no response, altered surfacing and diving behaviour, and changes in swimming direction. The most common reaction was a decline in descent speed and a reduction in bottom time, which suggests a change in behaviour from foraging to horizontal movement. The distances at which seals responded varied significantly; in one instance a grey seal showed responses at 45 km from the pile location, while other grey seals showed no response when within 12 km. Differences in responses could be attributed to differences in hearing sensitivity between individuals, differences in sound transmission with environmental conditions or the behaviour and motivation for the seal to be in the area. The telemetry data also showed that seals returned to the pile driving area after pile driving ceased.

4.10.4.26 As with harbour seals, the expert elicitation workshop in Amsterdam in 2018, (Booth *et al.* 2019) concluded that grey seals were considered to have a reasonable ability to compensate for lost foraging opportunities due to their generalist diet, mobility, life history and adequate fat stores and that the survival of 'weaned of the year' animals and fertility were determined to be most sensitive parameters to disturbance (i.e. reduced energy intake). However, in general, experts agreed that grey seals would be much more robust than harbour seals to the effects of disturbance due to their larger energy stores and more generalist and adaptable foraging strategies. It was agreed that grey seals would require ~185 days of repeated disturbance before there was any effect on fertility rates, range 100->300 days) to reduce fertility and >250 days of repeated disturbance to reduce fertility to zero. As with harbour seals, the 'weaned of the year' were considered to be most vulnerable following the post-weaning fast, and that during this time it might take ~60 days of repeated disturbance before there was expected to be any effect on weaned-of-the-year survival, however there was a lot of uncertainty surrounding this estimate (ranging between <50 days and >200 days).

4.10.4.27 Grey seals are capital breeders and store energy in a thick layer of blubber, which means that, in combination with their large body size, they are tolerant of periods of fasting as part of their normal life history. Grey seals are also highly adaptable to a changing environment and are capable of adjusting their metabolic rate and foraging tactics, to compensate for different periods of energy demand and supply (Beck *et al.* 2003, Sparling *et al.* 2006). Grey seals are also very wide ranging and are capable of moving large distances between different haul out and foraging regions (Russell *et al.* 2013). Therefore, they are unlikely to be particularly sensitive to displacement from foraging grounds during periods of active piling.

4.10.4.28 Taking the above into consideration, grey seals have been assessed as having **low** sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

*Porpoise sensitivity to vessel disturbance*

4.10.4.29 Given their high-frequency hearing range, it has been suggested that porpoise are more likely to be sensitive to vessels that produce medium to high frequency noise components (Hermannsen *et al.* 2014). However, harbour porpoise are known to avoid vessels and behavioural responses have been shown in porpoise exposed to vessel noise that contains low levels of high-frequency components (Dyndo *et al.* 2015). Thomsen *et al.* (2006) estimated that porpoise will respond to both small (~2 kHz) and large (~0.25 kHz) vessels at approximately 400 m. Wisniewska *et al.* (2018) presented data that suggested that porpoises may respond to very close range vessel passes with an interruption in foraging. However observed responses were short lived, porpoises were observed to resume foraging 10 minutes after a very close-range vessel encounter. Tagged porpoises remained in areas where shipping levels were high. Overall, despite animals remaining in heavily trafficked areas, the incidence of responses to vessels was low, indicating little fitness cost to exposure to vessel noise and any local scale responses taken to avoid vessels. It is likely that porpoise may become habituated where vessel movements are regular and predictable where as they may be are expected to show more of a local behavioural response to novel vessel activities related to construction activities. However, because the dose response relationships relating displacement to piling are based on data collected over periods including such vessel activity, these local responses to novel activity such as pile driving vessels have effectively already been included in the assessment of underwater noise related to pile driving above. Heinänen and Skov (2015) suggested that harbour porpoise density was significantly lower in areas with vessel transit rates of greater than 20,000 ships/year (80 per day). Vessel traffic in the Hornsea Four area will be below this figure (see **Volume 1, Chapter 4: Project Description**, the busiest period during construction in terms of vessel traffic would be when up to eight vessels are present in a given 5 $km^2$ block. This level of activity is unlikely to occur across the entire Hornsea Four array area at any one time, rather this intensity is expected across only approximately three or four 5 km$^2$ blocks). Therefore, the sensitivity of harbour porpoise is assessed as **low**.

*Minke whale sensitivity to vessel disturbance*

4.10.4.30 There is limited information available on the responses of minke whales to vessels. Whale watching vessels that specifically target minke whales have been shown to cause behavioural responses in minke whales and repeated exposure can result in a decrease in foraging activity (Christiansen *et al.* 2013). However, these are vessels which specifically target and follow minke whales so it is unknown whether minke whales respond to more general ship traffic. A maximum design is assumed  that vessel disturbance could result in temporary displacement of minke whales from the immediate area, however there is no evidence that the Hornsea Four area is an important foraging habitat for minke whales, and given their generalist and varied diet, it is not expected that any temporary displacement resulting from vessel activity in relation to the Hornsea Four will lead to any significant effect on individual energy budgets and subsequently fitness. Therefore, the sensitivity of minke whales to vessel disturbance is assessed as **low**.

*White-beaked dolphin sensitivity to vessel disturbance*

4.10.4.31 There is limited information available on the responses of white-beaked dolphins to vessels. Due to a lack of data, bottlenose dolphins can be used as a proxy species for white-beaked dolphins as they are both included within the High Frequency cetacean functional hearing group (Southall *et al.* 2019). Pirotta *et al.* (2015) found that transit of vessels in the Moray Firth resulted in a reduction (by almost half) of the likelihood of recording bottlenose dolphin prey capture buzzes. They also suggest that vessel presence, not just vessel noise, resulted in disturbance. There is however likely to be rapid recovery from disturbance from vessel presence and vessel noise, as they recorded little pre-emptive disturbance or recovery time following disturbance. There is evidence of bottlenose dolphin habituation to boat traffic, particularly in relation to larger vessel types (Sini *et al.*, 2005). Lusseau *et al.* (2011) undertook a modelling study which predicted that increased vessel movements associated with offshore wind development in the Moray Firth did not have a negative effect on the local population of bottlenose dolphin, although it did note that foraging may be disrupted by the disturbance from vessels. Therefore, bottlenose dolphins as a proxy for white-beaked dolphins have been assumed to have a **low** sensitivity.

*Seal sensitivity to vessel disturbance*

4.10.4.32 Jones *et al.* (2017) presents an analysis of the predicted co-occurrence of ships and seals at sea which demonstrates that UK wide there is a large degree of predicted co-occurrence, particularly within 50 km of the coast close to seal haul-outs. There is no evidence relating decreasing seal populations with high levels of co-occurrence between ships and animals. In fact, in areas where seal populations are showing high levels of growth (e.g. southeast England) ship co-occurrences are highest (Jones *et al.* 2017). Thomsen *et al.* (2006) estimated that both harbour and grey seals will respond to both small (~2 kHz) and large (~0.25 kHz) vessels at approximately 400 m. The sensitivity of both seal species is assessed as **low**.

**Table 4.16: Summary of key marine mammal sensitivity assessments.**

| Species | Permanent Threshold Shift (PTS) | Behavioural disturbance from pile-driving | Behavioural disturbance from vessels |
|---|---|---|---|
| Harbour porpoise | **Medium** | **Medium** | **Low** |
| Minke whale | **Medium** | **Medium** | **Low** |
| White-beaked dolphin | **Medium** | **Medium** | **Low** |
| Harbour seal | **Low** | **Medium** | **Low** |
| Grey seal | **Low** | **Low** | **Low** |

#### 4.10.5 Assessment Limitations and Uncertainty

4.10.5.1 There are uncertainties relating to the underwater noise modelling and impact assessment for Hornsea Four. Broadly, these relate to predicting exposure of animals to underwater noise, predicting the response of animals to underwater noise and predicting potential population consequences of disturbance from underwater noise. Further detail of such uncertainty is set out below.

*PTS assessment assumptions*

4.10.5.2 All marine mammals were modelled to swim away at the onset of piling at a swimming speed of 1.5 m/s apart from minke whales which were modelled to flee at 3.25 m/s. There are data to suggest that these selected swim speeds are precautionary and that animals are likely to flee at much higher speeds, at least initially. Minke whales have been shown to flee from ADDs at a mean swimming speed of 4.2 m/s (McGarry *et al.* 2017). A recent study by Kastelein *et al.* (2018) showed that a captive harbour porpoise responded to playbacks of pile driving sounds by swimming at speeds significantly higher than baseline mean swimming speeds, with greatest speeds of up to 1.97 m/s which were sustained for the 30 minute test period. In another study, van Beest *et al.* (2018) showed that a harbour porpoise responded to an airgun noise exposure with a fleeing speed of 2 m/s. These recent studies have demonstrated porpoise and minke whale fleeing swim speeds that are greater than that used in the fleeing model here, which makes the modelled speeds used in this assessment precautionary. The modelled swimming speeds were presented to the consultees in the Evidence Plan Note: Noise Modelling Methodology and Approach and no concerns were raised in subsequent consultee comments (February 2019).

4.10.5.3 There is likely to be much more uncertainty associated with the prediction of levels of cumulative exposure due to the difficulty in predicting the true levels of sound exposure over long periods of time, as a result of uncertainties about responsive movement, the position of animals in the water column, extent of recovery between pulses or in breaks in piling and the extent to which pulsed sound loses its pulse like characteristics over time. As a result of this uncertainty, model parameters are generally highly conservative and therefore the resulting predictions are precautionary and unlikely to be realised.

4.10.5.4 Southall *et al.* (2019) acknowledges that as a result of propagation effects, the sound signal of certain sound sources (e.g. pile driving) loses its impulsive characteristics and could potentially be characterised as non-impulsive beyond a certain distance. The changes in noise characteristics with distance generally result in exposures becoming less physiologically damaging with increasing distance as sharp transient peaks become less prominent (Southall *et al.* 2007). The Southall *et al.* (2019) updated criteria proposed that, while keeping the same source categories, the exposure criteria for impulsive and non-impulsive sound should be applied based on the signal features likely to be perceived by the animal rather than those emitted by the source. Methods to estimate the distance at which the transition from impulsive to non-impulsive noise are currently being developed (Southall *et al.* 2019).

4.10.5.5 There were four criteria that were proposed by the National Oceanic and Atmospheric Administration (NOAA) guidance in its 2015 draft version (and were removed from the final 2016 guidance) based on signal duration[1], rise time[2], crest factor[3] and peak pressure[4] divided by signal duration[5]. Using these criteria, Hastie *et al.* (2019) estimated the transition from impulsive to non-impulsive characteristics of pile driving noise during the installation of offshore wind turbine foundations at the Wash and in the Moray Firth. They showed that the noise signal experienced a high degree of change in its impulsive characteristics with increasing distance (see **Appendix A** for details). Based on this data it is expected that piling noise will transition from impulsive signals to non-impulsive signals at a range between 2-5 km from the piling source. Predicted PTS impact ranges based on the impulsive noise thresholds will therefore be overestimates in cases where the impact ranges lie beyond this. Any animal present beyond that distance when piling starts will only be exposed to non-impulsive noise, and therefore impact ranges should be based on the non-impulsive thresholds. In this impact assessment the full modelled PTS impact ranges using the impulsive thresholds are presented. In addition to this, where PTS impact ranges are predicted to be large, an assessment will also be provided under the assumption that impulsive PTS ranges will not realistically extend beyond 2-5 km.

4.10.5.6 It is also important to note that it is expected that only 18-19% of animals are predicted to actually experience PTS at the PTS onset threshold level. This was the approach adopted by Donovan *et al.* (2017) to develop their dose response curve implemented into the SAFESIMM model, based on the data presented in Finneran *et al.* (2005). Therefore, where PTS onset ranges are provided, it is not expected that all individuals within that range will experience PTS. Therefore, the number of animals predicted to be within PTS onset ranges are precautionary.

*Exposure of marine mammals to noise*

4.10.5.7 There are uncertainties relating to the ability to predict the exposure of animals to underwater noise, as well as in predicting the response to that exposure. These uncertainties

[1] Time interval between the arrival of 5% and 95% of total energy in the signal.
[2] Measured time between the onset (defined as the 5thpercentile of the cumulative pulse energy) and the peak pressure in the signal.
[3] The decibel difference between the peak sound pressure level (i.e. the peak pressure expressed in units of dB re 1 μPa) of the pulse and the root-mean-square sound pressure level calculated over the signal duration.
[4] The greatest absolute instantaneous sound pressure within a specified time interval.
[5] Time interval between the arrival of 5% and 95% of total energy in the signal.

relate to a number of factors: the ability to predict the level of noise that animals are exposed to, particularly over long periods of time; the ability to predict the numbers of animals affected, and the ability to predict the individual and ultimately population consequences of exposure to noise. These are explored in further detail in the paragraphs below.

4.10.5.8 The propagation of underwater noise is relatively well understood and modelled using standard methods. However, there are uncertainties regarding the amount of noise actually produced by each pulse at source and how the pulse characteristics change with range from the source. There are also uncertainties regarding the position of receptors in relation to received levels of noise, particularly over time, and understanding how position in the water column may affect received level. Noise monitoring is not always carried out at distances relevant to the ranges predicted for effects on marine mammals, so effects at greater distances remain un-validated in terms of actual received levels. The extent to which ambient noise and other anthropogenic sources of noise may mask signals from the offshore wind farm construction are not specifically addressed. The dose-response curves for porpoise include behavioural responses at noise levels down to 120 dB $SEL_{ss}$ which may be indistinguishable from ambient noise at the ranges these levels are predicted (see **Volume 4, Annex 4.5: Subsea Noise Technical Report**, ambient noise levels in the Hornsea Zone are between 112-122 dB re 1μPa RMS).

4.10.5.9 It is important to note that the $SEL_{cum}$ thresholds were determined with the assumption that a) the amount of sound energy an animal is exposed to within 24 hours will have the same effect on its auditory system, regardless of whether it is received all at once or in several smaller doses spread over a longer period (called the equal-energy hypothesis), and b) the sound keeps its impulsive character, regardless of the distance to the sound source. Both assumptions lead to a conservative determination of the impact ranges, as a) the magnitude of TTS induced might be influenced by the time interval in-between successive pulses, with some time for TTS recovery in-between pulses (e.g. Finneran *et al.* 2010, Kastelein *et al.* 2013, Kastelein *et al.* 2014) therefore recovery is possible in the gaps between individual pile strikes and in the breaks in piling activity, and b) an impulsive sound will eventually lose its impulsive character while propagating through the water column, therefore becoming non-impulsive (as described in NMFS 2018), and then causing a smaller rate of threshold shift (see above). Analysis of pile driving data by researchers at SMRU has demonstrated that pile strikes may lose their pulse characteristics at ranges of circa 2-5 km (see **Appendix A**) (Hastie *et al.* 2019). Modelling the $SEL_{cum}$ impact ranges of PTS with a 'fleeing animal' model, as is typical in noise impact assessments, are subject to both of these uncertainties and the result is a highly precautionary prediction of impact ranges.

4.10.5.10 There are very few data available on the underwater noise levels produced by operational wind farms, however, it is expected that the operational noise produced by WTGs will increase with increasing rotor size. The MDS for Hornsea Four is a WTG rotor diameter of 305 m, however there are currently no measured empirical data on the sound that these size turbines will produce. Therefore, an assessment was made based on extrapolations from measured data from operational offshore wind farms sites with smaller sizes rotors (see **Volume 4, Annex 4.5: Subsea Noise Technical Report**). Data were available for the underwater noise generated by WTGs with rotor diameters between 107 and 120 m at a range of water depths from 0 to 15 m in a range of sediment types. These are smaller than the maximum 305 m rotor diameter at Hornsea Four, and in shallower waters than at Hornsea Four. Subacoustech assumed a linear fit to extrapolate the data out to larger rotor diameters, however it was highlighted that this was the most conservative extrapolation method and that this will likely overestimate true operational noise levels. This approach is in line with the NPL Good Practice Guide 133 for underwater noise measurements (Robinson *et al.* 2014) which advises that under certain circumstances, a simple modelling approach may more appropriate; such as when detailed modelling would imply an unwarranted accuracy (e.g. where data is limited such as with large operational WTG noise). Further details on the limitations of the data and this approach are outlined in **Volume 4, Annex 4.5: Subsea Noise Technical Report**.

4.10.5.11 There is also a lack of data on the underwater noise produced by the clearance of various different types and sizes of UXO, and the current models to predict the noise propagation have not been validated at ranges relevant to the predictions and there is a possibility that models significantly overestimate ranges for large charge masses. Therefore, where there are empirical and modelled data available on impact ranges from UXO clearance, these have been presented to provide an estimate for the potential impacts at Hornsea Four. Until a UXO survey has been completed at Hornsea Four, it is unknown how many or what size UXO will require clearance. Hornsea Project One identified 23 UXO targets that required in-situ detonation and therefore a similar number could be expected for Hornsea Project Four across the Hornsea Four array area and offshore cable corridor and is considered a realistic assumption. Note: UXO clearance will not be included in the application at this stage, however a high-level assessment is provided on the basis of assumptions about the expected level of risk. A detailed assessment of UXO clearance will be developed for a separate marine licence at a later stage (this approach was agreed with the MMO 26 November 2018 – see **Volume 1, Chapter 4: Project Description**).

*Predicting the Response of Animals to Underwater Noise*

4.10.5.12 There are uncertainties relating to the ability to predict the responses of animals to underwater noise and the prediction of the numbers of animals potentially exposed to levels of noise that may cause an impact is uncertain. Given the high spatial and temporal variation in marine mammal abundance and distribution in any particular area of the sea, it is difficult to confidently predict how many animals may be present within the range of noise impacts. All methods for determining at sea abundance and distribution suffer from a range of biases and uncertainties and no single method or data source will provide a complete prediction of future conditions. The marine mammal baseline (**Volume 5, Annex 4.1: Marine Mammal Technical Report**) details the data sources used in the assessment and the most robust estimates of density have been agreed with the Evidence Plan Technical Panel (Meeting 30 April 2019 and 26 June 2019).

4.10.5.13 In addition, there is limited empirical data available to confidently predict the extent to which animals may experience auditory damage or display responses to noise. The current methods for prediction of behavioural responses are based on received sound levels, but it is likely that factors other than noise levels alone will also influence the probability of response and the strength of response (e.g. previous experience, behavioural and physiological context, proximity to activities, characteristics of the sound other than level, such as duty cycle and pulse characteristics). However, at present, it is impossible to adequately take these factors into account in a predictive sense. This assessment makes use of the monitoring work that has been carried out during the construction of the Beatrice Offshore Wind Farm and therefore uses the most recent and site-specific information on disturbance to harbour porpoise as a result of pile driving noise.

4.10.5.14 There is also a lack of information on how observed effects (e.g. short-term displacement around pile-driving activities) manifest themselves in terms of effects on individual fitness, and ultimately population dynamics (see the section above on marine mammal sensitivity to disturbance and the recent expert elicitation conducted for harbour porpoise and both seal species) in order to attempt to quantify the amount of disturbance required before vital rates are impacted.

4.10.5.15 The duration of disturbance is another uncertainty. Studies at Horns Rev 2 demonstrated that porpoises returned to the area between 1 and 3 days (Brandt *et al.* 2011) and monitoring at the Dan Tysk Wind Farm as part of the DEPONS project found return times of around 12 hours (van Beest *et al.* 2015). Two studies at Alpha Ventus demonstrated, using aerial surveys, that the return of porpoises was about 18 hours after piling (Dähne *et al.* 2013). A recent study of porpoise response at the Gemini wind farm in the Netherlands, also part of the DEPONS project, found that local population densities recovered between two and six hours after piling (Nabe-Nielsen *et al.* 2018). An analysis of data collected at the first seven offshore windfarms in Germany has shown that harbour poise detections were reduced between 1-2 days after piling (Brandt *et al.* 2018). Analysis of data from monitoring of marine mammal activity during piling of jacket pile foundations at Beatrice Offshore Wind Farm is ongoing (Graham *et al.* 2017a, Graham *et al.* 2018) but some initial outputs are available which provide useful information. There is evidence that harbour porpoise were displaced during pile driving but return after cessation of piling, with a reduced extent of disturbance over the duration of the construction period. This suggests that the assumptions adopted in the current assessment are precautionary as animals are predicted to remain disturbed at the same level for the entire duration of the pile driving phase of construction.

4.10.5.16 There are no empirical data on the responses of minke whales to pile driving noise, but a recent study of responses to ADDs demonstrated that minke whales responded to ADD signals by swimming directly away from the noise source at speeds increased above baseline, and some individuals were found to return to the deployment site after the ADD playback ceased, suggesting possible recovery after 10-15 minutes (McGarry *et al.* 2017).

4.10.5.17 There are no empirical data on the threshold for auditory injury in the form of PTS onset for marine mammals, as to test this would be inhumane. Therefore, PTS onset thresholds are estimated based on extrapolating from Temporary Threshold Shift (TTS) onset thresholds. For pulsed noise, such as piling, NOAA have set the onset of TTS at the lowest level that exceeds natural recorded variation in hearing sensitivity (6 dB), and assumes that PTS occurs from exposures resulting in 40 dB or more of TTS measured approximately four minutes after exposure (NMFS 2018).

## 4.11 Impact assessment

### 4.11.1 Construction

4.11.1.1 The impacts of the offshore construction of Hornsea Four have been assessed on marine mammals. The environmental impacts arising from the construction of Hornsea Four are listed in **Table 4.10** along with the MDS against which each construction phase impact has been assessed.

4.11.1.2 A description of the potential effect on marine mammal receptors caused by each identified impact is given below.

### PTS (auditory injury) from piling noise (most likely piling scenario) (MM-C-1).

*Harbour porpoise*

4.11.1.3 **Table 4.17** indicates the areas and maximum ranges within which there is any risk of PTS onset occurring to harbour porpoise at each of the four modelling locations and how many animals are estimated to be within the PTS impact area based on survey derived average density estimates. The largest predicted PTS onset impact ranges reach a maximum of 3.8 km at the east modelling location for pin piles ($SEL_{cum}$) and 2.5 km at the north west location for monopiles ($SPL_{peak}$). The $SPL_{peak}$ PTS onset impact ranges at the beginning of the soft start are a maximum of 570 m for monopiles and 170 m for pin piles.

4.11.1.4 Although the numbers of individuals predicted to be at risk are low and would not be considered significant in EIA terms, harbour porpoise are an EPS and under EPS legislation it is an offence to injure a single individual (this includes PTS auditory injury). Therefore, Hornsea Four has committed to a piling MMMP (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register**) to reduce the risk of PTS to negligible levels (see **F2.5: Outline Marine Mammal Mitigation Protocol**). In addition to this embedded mitigation, it is also likely that the presence of novel vessels and associated construction activity will ensure that the vicinity of the pile is free of harbour porpoise by the time that piling begins.

**Table 4.17: Impact area, maximum range and number of harbour porpoise predicted to experience PTS for the most likely piling scenarios.**

| Full hammer energy | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| PTS Threshold | NW | E | S | HVAC | NW | E | S | HVAC |
| *Instantaneous PTS at full hammer energy: 202 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area (km²) | **20** | 14 | 14 | 19 | **5.6** | 4.1 | 4.2 | **5.6** |
| Max Range (m) | **2,500** | 2,200 | 2,100 | 2,500 | **1,300** | 1,200 | 1,200 | **1,300** |
| # Porpoise (aerial + SCANS III) | 35 (0.01%) | 24 (0.01%) | 24 (0.01%) | 17 (0.00%) | 10 (0.00%) | 7 (0.00%) | 7 (0.00%) | 5 (0.00%) |
| # Porpoise (acoustic + SCANS III) | **41 (0.01%)** | 37 (0.01%) | 20 (0.01%) | 40 (0.01%) | 12 (0.00%) | 11 (0.00%) | 6 (0.00%) | 12 (0.00%) |
| *155 dB VHF Weighted $SEL_{cum}$* | | | | | | | | |
| Area (km²) | <0.01 | <0.01 | <0.01 | <0.01 | **31** | 18 | 4.4 | 30 |
| Max Range (m) | <100 | <100 | <100 | <100 | 3,600 | **3,800** | 1,400 | 3,200 |
| # Porpoise (aerial + SCANS III) | <1 | <1 | <1 | <1 | 54 (0.02%) | 31 (0.01%) | 8 (0.00%) | 27 (0.01%) |
| # Porpoise (acoustic + SCANS III) | <1 | <1 | <1 | <1 | **66 (0.02%)** | 43 (0.01%) | 6 (0.00%) | 61 (0.02%) |
| **Soft start** | **Monopile (800 kJ)** | | | | **Pin pile (350 kJ)** | | | |
| *Instantaneous PTS at commencement of soft-start: 202 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area (km²) | **1** | 0.73 | 0.75 | 0.99 | **0.08** | 0.06 | 0.07 | **0.08** |
| Max Range (m) | **570** | 480 | 490 | 560 | **170** | 140 | 150 | **170** |

*Magnitude of impact*

4.11.1.5 The PTS impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. With the use of embedded mitigation methods (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register** and outlined in **F2.5: Outline Marine Mammal Mitigation Protocol**), it is expected that the risk of PTS will be negligible. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*Minke whale*

4.11.1.6 **Table 4.18** indicates the areas and maximum ranges within which there is any risk of PTS onset occurring to minke whales at each of the four modelling locations and how many animals are estimated to be within the PTS impact area. While the largest $SEL_{cum}$ PTS onset impact ranges are reasonably large (up to 5.8 km for monopiles at the east location), the density of minke whales in the area is very low and so the number of individual whales expected to experience PTS at each modelling location is very low (<1 for all scenarios). The $SPL_{peak}$ PTS onset impact ranges at the beginning of the soft start are <50 m for both monopiles and pin piles.

4.11.1.7 Although the numbers of individuals predicted to be at risk are very low and would not be considered significant in EIA terms, minke whales are an EPS and under EPS legislation it is an offence to injure a single individual. Therefore Hornsea Four has committed to a piling MMMP (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register**) to reduce the risk of PTS to negligible levels (see **F2.5: Outline Marine Mammal Mitigation Protocol**). In addition to the embedded mitigation, there is also the potential that the presence of vessels and associated activity will serve to displace minke whales from the immediate vicinity of the piling location prior to the start of piling.

**Table 4.18: Impact area, maximum range and number of minke whales predicted to experience PTS for the most likely piling scenarios.**

| Full hammer energy | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| *Instantaneous PTS at full hammer energy 219: dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area (km$^2$) | 0.04 | 0.03 | 0.04 | 0.04 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | 120 | 110 | 110 | 120 | 60 | 50 | 50 | 60 |
| # Whales<br>% of MU | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% | <1<br><0.5% |
| *183 dB LF Weighted $SEL_{cum}$* | | | | | | | | |
| Area (km$^2$) | 32 | 27 | 0.68 | 32 | 0.44 | 1.6 | <0.01 | 0.21 |
| Max Range (m) | 4,800 | **5,800** | 1,100 | 3,900 | 1,200 | 1,700 | <100 | 550 |
| # Whales | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |

| % of MU | <0.5% | <0.5% | <0.5% | <0.5% | <0.5% | <0.5% | <0.5% | <0.5% |
|---|---|---|---|---|---|---|---|---|
| **Soft start** | **Monopile (800 kJ)** | | | | **Pin pile (350 kJ)** | | | |
| *Unweighted Instantaneous PTS at commencement of soft-start: 219 dB $SPL_{peak}$* | | | | | | | | |
| Area (km$^2$) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |

4.11.1.8 Consideration needs to be given to the fact that impulsive sounds from pile driving have been shown to lose their impulsive characteristics (such as rise time) within 2-5 km from the source (Hastie *et al.* 2019). Therefore, the PTS onset impact range of 5.8 km using an impulsive threshold is an overestimate. PTS impact ranges for non-impulsive noise are <100 m for all piling locations for both monopiles and pin piles (**Table 4.19**). The most realistic PTS onset impact range is considered to be between 2 and 5 km.

**Table 4.19: Non-impulsive PTS impact ranges for minke whales for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| Area (km$^2$) | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Max Range (m) | < 100 | < 100 | < 100 | < 100 | < 100 | < 100 | < 100 | < 100 |

4.11.1.9 It should also be noted that the baseline characterisation data confirmed that minke whales are only present in the Hornsea Four area in the summer months, and therefore it is expected that they will only potentially be present over a few months each year.

*Magnitude of impact*

4.11.1.10 The PTS impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. With the use of embedded mitigation methods (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register** and outlined in **F2.5: Outline Marine Mammal Mitigation Protocol**), it is expected that the risk of PTS will be negligible. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*White-beaked dolphin*

4.11.1.11 **Table 4.20** indicates the areas and maximum ranges within which there is any risk of PTS onset occurring to white-beaked dolphins at each of the four modelling locations and how many animals estimated to be are within the PTS impact area. All modelling locations have very small PTS impact areas (<0.01 km$^2$) and less than one single dolphin is predicted to be within the PTS onset impact area at any one time. The $SPL_{peak}$ PTS onset impact ranges at the beginning of the soft start are <50 m for both monopiles and pin piles.

4.11.1.12 Although the numbers of individuals predicted to be at risk are very low and would not be considered significant in EIA terms, white-beaked dolphins are an EPS and under EPS legislation it is an offence to injure a single individual. Therefore Hornsea Four has committed to a piling MMMP (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register**) to reduce the risk of PTS to negligible levels (see **F2.5: Outline Marine Mammal Mitigation Protocol**). It should also be noted that the baseline characterisation data confirmed that white-beaked dolphins are only present in the area in the winter months, and therefore it is expected that they will only potentially be present during a few months of the construction period.

**Table 4.20: Impact area, maximum range and number of white-beaked dolphins predicted to experience PTS for the most likely piling scenarios.**

| Full hammer energy | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| *Instantaneous PTS at full hammer energy: 230 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area (km$^2$) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| # Dolphins | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *185 dB HF Weighted $SEL_{cum}$* | | | | | | | | |
| Area (km$^2$) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| # Dolphins | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| **Soft start** | **Monopile (800 kJ most likely)** | | | | **Pin pile (350 kJ)** | | | |
| *Instantaneous PTS at commencement of soft-start: 230 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area (km2) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |

*Magnitude of impact*

4.11.1.13 The impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. With the use of embedded mitigation methods (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register** and outlined in **F2.5: Outline Marine Mammal Mitigation Protocol**), it is expected that the risk of PTS will be negligible. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*Seal species*

4.11.1.14 **Table 4.21** indicates the areas and maximum ranges within which there is any risk of PTS onset occurring to seals at each of the four modelling locations and how many animals estimated to be are within the PTS impact area. The maximum PTS onset impact range is for monopiles at the northwest or HVAC locations where impact ranges reach a maximum of 150 m, however, seal density estimates are low in the area and so less than one single seal of each species is predicted to be within the PTS onset impact areas at any one time.

**Table 4.21: Impact area, maximum range and number of harbour and grey seals predicted to experience PTS for the most likely piling scenarios.**

| Full hammer energy | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| *Instantaneous PTS at full hammer energy: 218 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area ($km^2$) | 0.07 | 0.05 | 0.05 | 0.07 | 0.02 | <0.01 | <0.01 | 0.02 |
| Max Range (m) | **150** | 130 | 130 | **150** | 70 | 60 | 60 | 70 |
| # Harbour Seals | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| # Grey Seals | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *185 dB PCW Weighted $SEL_{cum}$* | | | | | | | | |
| Area ($km^2$) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| # Harbour Seals | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| # Grey Seals | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| **Soft start** | **Monopile (800 kJ)** | | | | **Pin pile (350 kJ)** | | | |
| *Instantaneous PTS at commencement of soft-start: 218 dB Unweighted $SPL_{peak}$* | | | | | | | | |
| Area ($km^2$) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Max Range (m) | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |

*Magnitude of impact*

4.11.1.15 The impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. With the use of embedded mitigation methods (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register** and outlined in **F2.5: Outline Marine Mammal Mitigation Protocol**), it is expected that the risk of PTS will be negligible. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

## PTS (auditory injury) from piling noise (maximum design piling scenario) (MM-C-1).

4.11.1.16 For white-beaked dolphins, harbour seals and grey seals, the maximum maximum design PTS onset impact range is <100 m (**Table 4.22**). Within this impact area there is predicted to be <1 animal of each species that may be at risk of auditory injury.

4.11.1.17 For harbour porpoise the maximum maximum design PTS onset impact range is 9.7 km for the installation of a pin pile at the northwest location. Within this impact area there are a predicted 461 animals (0.13% MU) that may be at risk of auditory injury (**Table 4.22**).

4.11.1.18 For minke whales the maximum design PTS onset impact range is 11 km for the installation of a monopile at the northwest location. Within this impact area there are a predicted four animals (0.02% MU) that may be at risk of auditory injury (**Table 4.22**).

**Table 4.22: Predicted PTS onset impact under the maximum design piling scenarios.**

| Species | Location | Threshold | Monopile (5,000 kJ) | | | Pin Pile (2,500 kJ) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Area ($km^2$) | Max Range (m) | # Animals | Area ($km^2$) | Max Range (m) | # Animals |
| Harbour porpoise | NW | $SPL_{peak}$ | 25 | 2,900 | 53 (0.02%) | 10 | 1,800 | 22 (0.01%) |
| | | $SEL_{cum}$ | 9.2 | 1,900 | 20 (0.01%) | **220** | **9,700** | **461 (0.13%)** |
| Minke whale | NW | $SPL_{peak}$ | 0.06 | 140 | <1 | 0.02 | 80 | <1 |
| | | $SEL_{cum}$ | **260** | **11,000** | **3.4 (0.02%)** | 160 | 8,900 | 2.1 (0.01%) |
| White-beaked dolphin | NW | $SPL_{peak}$ | <0.01 | <50 | <1 | <0.01 | <50 | <1 |
| | | $SEL_{cum}$ | <0.01 | <100 | <1 | <0.01 | <100 | <1 |
| Harbour seal | NW | $SPL_{peak}$ | 0.09 | 170 | <1 | 0.03 | 100 | <1 |
| | | $SEL_{cum}$ | 1.6 | 830 | <1 | <0.01 | <100 | <1 |
| Grey seal | NW | $SPL_{peak}$ | 0.09 | 170 | <1 | 0.03 | 100 | <1 |
| | | $SEL_{cum}$ | 1.6 | 830 | <1 | <0.01 | <100 | <1 |

4.11.1.19 As outlined in **Appendix A**, using a benchmark probability of 80%, impulsive sounds from pile driving have been shown to lose their impulsive characteristics over the range of 2-5 km from the source (Hastie *et al.* 2019). Therefore, the PTS onset impact ranges of 9.7 km (for porpoise) and 11 km (for minke whales) using an impulsive threshold are an overestimate. The most realistic PTS onset impact range is considered to be between 2 and 5 km, therefore **Table 4.23** presents the number of animals impacted assuming these ranges.

**Table 4.23: Assessment of PTS onset for harbour porpoise and minke whales assuming a PTS onset impact range of either 2 or 5 km (northwest location).**

| Species | Harbour Porpoise | | Minke Whale | |
|---|---|---|---|---|
| PTS onset impact range | 2 km | 5 km | 2 km | 5 km |
| # animals within this area that may be at risk of auditory injury | **26** | 166 | <1 | <1 |
| % MU | 0.01% | 0.05% | 0.00% | 0.00% |

4.11.1.20 The maximum design PTS impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. With the use of embedded mitigation methods (Commitment Co110 of **Volume 4, Annex 5.2 Commitment Register** and outlined in **F2.5: Outline Marine Mammal Mitigation Protocol**), it is expected that the risk of PTS will be negligible. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*Summary of marine mammal PTS from piling noise*

4.11.1.21 The impact of PTS from piling noise under both the most likely and the maximum design scenarios is not considered to have a significant effect on any marine mammal species considered in this assessment.

### Behavioural disturbance from piling noise (most likely piling scenario) (MM-C-2).

4.11.1.22 Full details of the underwater noise modelling conducted to obtain the disturbance impact ranges are detailed in **Volume 4, Annex 4.5: Subsea Noise Technical Report**.

*Harbour porpoise*

4.11.1.23 **Table 4.24** indicates the number of harbour porpoise potentially disturbed by pile driving at each modelling location for both monopiles and pin piles. The highest level of disturbance in spatial terms is predicted to be from the installation of a monopile at the northwest location. Using the former Hornsea Zone acoustic density surface and SCANS III beyond that, a total of 6,136 porpoise are predicted to be potentially disturbed once hammer energy reaches its maximum, which represents 1.78% of the reference population. The equivalent number during pin pile installation at the same location is 4,717 animals (1.37% of the population) which represents the highest level of disturbance in temporal terms.

4.11.1.24 As outlined in **Table 4.10**, all disturbance will occur intermittently over a maximum period of 12 months foundation installation, with monopiles requiring fewer total piling days than pin piles. Given the results of the recent expert elicitation on the likely effects of behavioural disturbance on vital rates (Booth *et al.* 2019) (see **paragraph 4.10.4.14**), this number of days of repeated disturbance is unlikely to cause any effect on fertility rates, although there is the potential for calf survival to be affected. However, it is highly unlikely that the same mother-calf pair would repeatedly return to the area in order to receive these levels of repeated disturbance over this many days. Any potential impact on calf survival rates is likely to be temporary and is not expected to result in any changes in the population trajectory or overall size.

**Table 4.24: Number of harbour porpoise predicted to experience potential behavioural disturbance for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| *Former Hornsea Zone acoustic density surface + SCANS III* | | | | | | | | |
| Number of animals | **6,136** | 5,293 | 5,081 | 5,138 | **4,717** | 3,919 | 3,825 | 3,977 |
| % of MU | **1.78%** | 1.53% | 1.47% | 1.49% | **1.37%** | 1.13% | 1.11% | 1.15% |
| *Hornsea Four aerial survey average density + SCANS III* | | | | | | | | |
| Number of animals | 4,522 | 3,648 | 3,451 | 3,479 | 3,431 | 2,789 | 2,671 | 2,633 |
| % of MU | 1.31% | 1.06% | 1.00% | 1.01% | 0.99% | 0.81% | 0.77% | 0.76% |

*Magnitude of impact*

4.11.1.25 The impact is predicted to be of local spatial extent, short term duration, intermittent and is reversible. The extent of the impact in terms of the number of animals affected, the proportion of the MU affected, and the duration of impact is minor. The magnitude is therefore considered to be **minor**.

*Sensitivity of the receptor*

4.11.1.26 As outlined in **paragraph 4.10.4.14** onwards, disturbance as result of pile driving may temporarily affect harbour porpoise fertility and the probability of calf survival. Due to observed responsiveness to piling, and their income breeder life history, the sensitivity of harbour porpoise is therefore considered to be **medium**.

*Significance of the effect*

4.11.1.27 Overall, the sensitivity of harbour porpoise to disturbance has been assessed as **medium** and the magnitude is predicted to be **minor**. The effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.1.28 None proposed beyond existing commitments (Co110, see **Volume 4, Annex 5.2 Commitment Register)**.

*Minke whale*

4.11.1.29 **Table 4.25** indicates the number of minke whales potentially disturbed by pile driving at each modelling location for both monopiles and pin piles. The highest level of disturbance in spatial terms is predicted from the installation of a monopile at the northwest location, where a total of 45 minke whales are predicted to be potentially disturbed as a result of the installation of a monopile, which represents 0.23% of the reference population. The equivalent number for pin piles is 34 animals (0.17% of the MU) which represents the highest level of disturbance in temporal terms.

4.11.1.30 As outlined in **Table 4.10**, all piling related disturbance will occur over a maximum of 12 months, with monopiles requiring fewer total piling days than pin piles. According to the best available knowledge on the topic, as provided in an expert elicitation: "*Experts felt disturbance may result in reduced feeding and an increase in energetic costs of movement and therefore a reduction in body condition and elevated stress levels*" which the experts agreed could in turn affect fertility rates (Harwood *et al.* 2014); although expert opinion varied quite considerably on the duration of disturbance required to result in a reduction in fertility. A total of up to 45 individuals may be affected during piling therefore the most conservative assumption would be that individuals are repeatedly disturbed and that the total disturbance results in a failure of a small proportion of the MU to breed in the year of disturbance. However, this is considered highly unlikely as disturbed animals would probably move away from the area and not be subject to repeated disturbance. This level of disturbance is not expected to have a lasting effect on the overall population trajectory.

4.11.1.31 It should also be noted that the baseline characterisation data confirmed that minke whales are only present in the area in the summer months (May-Aug during the site-specific aerial surveys), and therefore it is expected that they will only be disturbed during the summer months.

**Table 4.25: Number of minke whales predicted to experience potential behavioural disturbance for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| Number of animals | **45** | 25 | 21 | 38 | **34** | 18 | 15 | 30 |
| % of MU | **0.23%** | 0.13% | 0.11% | 0.20% | **0.17%** | 0.09% | 0.08% | 0.15% |

*Magnitude of impact*

4.11.1.32 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The extent of the impact in terms of the number of animals, the proportion of the MU affected, and the duration of the impact is negligible. The magnitude is therefore considered to be **negligible** for minke whales and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*White-beaked dolphin*

4.11.1.33 **Table 4.26** indicates the number of white-beaked dolphins potentially disturbed by pile driving at each modelling location for both monopiles and pin piles. The highest level of disturbance in spatial terms is predicted from the installation of a monopile at the northwest location, where a total of 85 white-beaked dolphins are predicted to be disturbed, which represents 0.21% of the reference population. The equivalent number for pin piles at the same location is 70 animals (0.18% of the population) which represents the highest level of disturbance in temporal terms.

4.11.1.34 As outlined in **Table 4.10**, all disturbance will occur intermittently over a maximum period of 12 months, with monopiles requiring fewer total piling days than pin piles. White-beaked dolphins were not included as part of the expert elicitation process, therefore it is not possible to present equivalent expert elicitation findings for this species. However, given that there is information for bottlenose dolphins, and that both species are grouped together as mid-frequency cetaceans, the results of a previous bottlenose dolphin expert explication (Harwood *et al.* 2014) can be used as a proxy for white-beaked dolphins. The experts agreed that disturbance could (depending on the levels) result in some reduction in fecundity, calf and juvenile survival rates. Therefore, there is potential to be a small risk of failure to breed or an increased probability of calf and juvenile survival in the year in which disturbance occurs for a very small proportion of the population. This is not expected to have a lasting effect on the trajectory or size of the population.

4.11.1.35 It should also be noted that the baseline characterisation data confirmed that white-beaked dolphin sightings were are only predominant in the area in the winter months (Nov-

Jan during the site-specific aerial surveys), and therefore it is expected that they will only potentially be present over a few months of construction.

**Table 4.26: Number of white-beaked dolphins predicted to experience potential behavioural disturbance for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| Number of animals | **85** | 28 | 32 | 74 | **70** | 22 | 23 | 62 |
| % of MU | **0.21%** | 0.07% | 0.08% | 0.19% | **0.18%** | 0.05% | 0.06% | 0.16% |

*Magnitude of impact*

4.11.1.36 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The extent of the impact in terms of the number of animals affected, the proportion of the MU affected, and the duration of impact is negligible. The magnitude is therefore, considered to be **negligible** for white-beaked dolphins and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*Harbour seal*

4.11.1.37 **Table 4.27** indicates the number of harbour seals potentially disturbed by pile driving at each modelling location for both monopiles and pin piles. The highest disturbance levels were predicted for the south location, where a total of 45 harbour seals are predicted to be disturbed for the installation of a monopile, which represents 0.78% of the reference population. The equivalent number for pin piles at the same location is 27 animals (0.47% of the population) which represents the highest level of disturbance in temporal terms.

4.11.1.38 As outlined in **Table 4.10**, all disturbance will occur intermittently over a maximum period of 12 months, with monopiles requiring fewer total piling days than pin piles. Given the results of the recent expert elicitation on the likely effects of behavioural disturbance on vital rates (Booth *et al.* 2019) (see **Section 4.10.4**), there is the potential for this level of disturbance to cause an effect on fertility rates and survival of 'weaned of the year' animals, however expert opinions varied greatly on the number of days of repeated disturbance that this would require. Given that the area has an estimated low density of harbour seals, it is not considered to be an important foraging area for the species. Therefore, any disturbance and displacement is unlikely to result in a significant reduction in energy intake. In addition, data collated during windfarm construction has shown that harbour seal density quickly recovers once piling has ceased, and so any disturbance is likely to be short lived and temporary in nature.

**Table 4.27: Number of harbour seals predicted to experience behavioural disturbance for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| Number of animals | 3 | 23 | **45** | 7 | 1 | 11 | **27** | 3 |
| % of MU | 0.05% | 0.40% | **0.78%** | 0.12% | 0.02% | 0.19% | **0.47%** | 0.05% |

*Magnitude of impact*

4.11.1.39 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The extent of the impact in terms of the number of animals affected, the proportion of the MU affected, and the duration of impact is negligible. The magnitude is therefore, considered to be **negligible** for harbour seals and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

*Grey seal*

4.11.1.40 **Table 4.28** indicates the number of grey seals potentially disturbed by pile driving at each modelling location for both monopiles and pin piles. The highest potential disturbance levels on a spatial basis were predicted for the northwest location where a total of 839 grey seals are predicted to be disturbed for the installation of a monopile, which represents 1.83% of the reference population. The equivalent number for pin piles at the same location is 383 animals (0.84% of the population) which represents the highest level of disturbance in temporal terms.

4.11.1.41 As outlined in **Table 4.10**, all disturbance will occur intermittently over a maximum period of 12 months, with monopiles requiring fewer total piling days than pin piles. Given the results of the recent expert elicitation on the likely effects of behavioural disturbance on vital rates (Booth *et al.* 2019) (see **Section 4.10.4**), there is the potential for this level of disturbance to cause an effect on fertility rates and survival of 'weaned of the year' animals if repeated disturbance were to result in a significant reduction in foraging and therefore energy intake; however expert opinions varied greatly on the number of days of repeated disturbance that this would require. Data collated during windfarm construction has shown that seals quickly return to the area once piling has ceased, and so any disturbance is likely to be short lived and temporary in nature (Russell *et al.* 2016). In addition, telemetry data have shown that not all grey seals respond to pile driving (Aarts *et al.* 2018), and so may not be disturbed and displaced out of an area that that are motivated to stay in for foraging.

4.11.1.42 Overall there is the potential for a risk of a decline in fertility and survival of 'weaned of the year' for a very small proportion of the population if animals are repeatedly displaced from foraging areas over the 12 month construction period.

**Table 4.28: Number of grey seals predicted to experience behavioural disturbance for the most likely piling scenarios.**

| | Monopile (4,000 kJ) | | | | Pin pile (1,750 kJ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NW | E | S | HVAC | NW | E | S | HVAC |
| Number of animals | **839** | 157 | 107 | 702 | **383** | 56 | 56 | 383 |
| % of MU | **1.83%** | 0.34% | 0.23% | 1.53% | **0.84%** | 0.12% | 0.12% | 0.84% |

4.11.1.43 The at-sea usage data suggest that there is a potential foraging area to the northwest of the array area, as shown by the higher predicted densities in the grid cells in **Figure 4.4**. The dose response curve used for grey seal behavioural responses was produced from data obtained from tagged harbour seals only, and there is currently no grey seal dose response curve available. Grey seals are considered to be less sensitive to behavioural disturbance than harbour seals (see **Section 4.10.4**), and recent studies of tagged grey seals have shown that there is vast individual variation is responses to pile driving, with some animals not showing any evidence of a behavioural response when within 12 km of the pile driving location (Aarts *et al.* 2018). Therefore the adoption of the harbour seal dose response curve for grey seals is likely to over-estimate the potential for impact on grey seals.

4.11.1.44 The highest density grid cells (red grid cells in **Figure 4.4**) are located between 10 and 22 km from the northwest piling location and are situated within the $SEL_{ss}$ contours 155≤160 and 160≤165 dB (**Figure 4.4**). It is important to note that not all grey seals within these noise level contours are expected to respond during pile driving. Given the distance of the highest density areas from the northwest pile location, based on the data presented in Aarts *et al.* (2018) it is possible that grey seals may show no behavioural response at all, given their motivation to remain in the area for foraging. Given the wide ranging behaviour of grey seals, travelling over 100 km between haul-out sites and with foraging trips lasting up to 30 days (SCOS 2017), it is highly likely that any grey seals displaced from this foraging area will be able to compensate by travelling to a different foraging patch. Telemetry data obtained from grey seals tagged at Donna Nook in the Humber Estuary SAC (**Figure 4.4**) show that the foraging area to the northwest of the array area is not the only foraging location that these seals utilise (characterised by high densities of location fixes with tight turning angles in tracks).

4.11.1.45 Similarly it is expected that some grey seals may be displaced around the HVAC location at the time of piling, however pile driving at this site will be temporary in nature and since not all seals are predicted to respond they will still be expected to transit through and around this area from the Humber Estuary SAC in order to reach foraging sites.

4.11.1.46 This type of short-term, intermittent and temporary behavioural response will affect only a very small proportion of the population and, while energetic requirements may be slightly increased by the need to transit to another foraging location, survival and reproductive rates are very unlikely to be impacted.

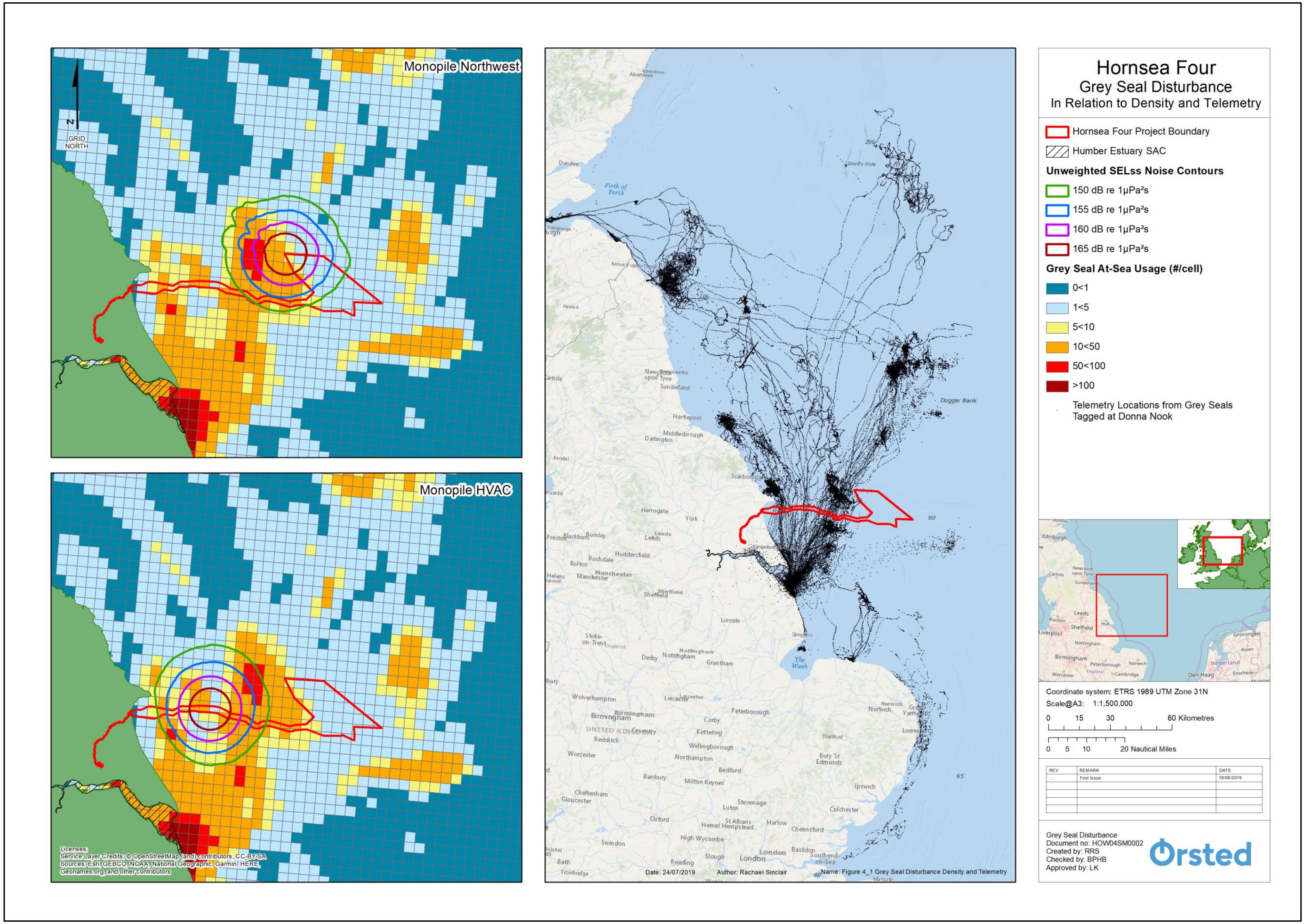


Figure 4.4: Left: Dose response noise impact contours in relation to a grey seal at-sea usage. No grey seals are predicted to respond beyond the 150 dB contour. Within the 150≤155 dB contour 28% of seals are predicted to respond, within the 155≤160 dB contour 49% are predicted to respond, within the 160≤165 dB contour 68% are predicted to respond and within the 165 dB contour all seals are predicted to respond. Right: Telemetry locations from 22 grey seals tagged at Donna Nook (not to scale).

*Magnitude of impact*

4.11.1.47 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The extent of the impact in terms of the number of animals affected, the proportion of the MU affected, and the duration of impact is minor. The magnitude is therefore considered to be **minor** for grey seals.

*Sensitivity of the receptor*

4.11.1.48 As outlined in **paragraph 4.10.4.20** onwards, the sensitivity of grey seals is considered to be **low**.

*Significance of the effect*

4.11.1.49 Overall, the sensitivity of grey seals to disturbance has been assessed as **low** and the magnitude is predicted to be **minor**. The effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.1.50 None proposed beyond existing commitments (see **Volume 4, Annex 5.2 Commitment Register)**.

*Summary of potential behavioural disturbance from piling noise (most likely)*

4.11.1.51 The impact of behavioural disturbance from piling noise under the most likely scenario is not considered to have a significant effect on any marine mammal species considered in this assessment.

**Table 4.29: Summary of predicted significance of impacts to marine mammals resulting from behavioural disturbance under the most likely scenario.**

| Species | Magnitude | Sensitivity | Significance |
|---|---|---|---|
| Harbour porpoise | **Minor** | **Medium** | **Minor Adverse** (not significant in EIA terms) |
| Minke whale | **Negligible** | **-** | **Not significant** |
| White-beaked dolphin | **Negligible** | **-** | **Not significant** |
| Harbour seal | **Negligible** | **-** | **Not significant** |
| Grey seal | **Minor** | **Low** | **Minor Adverse** (not significant in EIA terms) |

### Behavioural disturbance from piling noise (maximum design piling scenario) (MM-C-2).

4.11.1.52 The results from the most likely piling scenario were used to identify which noise modelling location represented the highest level of disturbance for each species and these locations were then used for analysis of the maximum design scenario for behavioural disturbance; the results are presented in **Table 4.30**. The results demonstrate that there is only a very small increase in the number of animals predicted to experience behavioural disturbance between the most likely and the maximum design scenarios (between 3.5% and 8.9% increase in numbers depending on species). For monopiles it is estimated that the maximum hammer energy may occur on 65 days over the 12 month construction period (assuming 1.2 monopiles are installed per day), and for pin piles it is estimated that the maximum hammer energy may occur on 81 days over the 12 month construction period (assuming 1.5 jacket foundations are installed per day).

4.11.1.53 Given the number of animals and proportion of the MU predicted to be impacted, the magnitude of the impact of behavioural disturbance from the maximum design scenario is assessed as **minor** for both harbour porpoise and grey seals. Combined with the sensitivity assessment (see **paragraph 4.10.4.9** onwards and **Table 4.30**), this results in a **minor** adverse significance for harbour porpoise, which is not significant in EIA terms and a Not Significant impact on grey seals. For all other species the impact is predicted to be of **negligible** magnitude and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**) Therefore the assessment for the maximum design scenario was the same as for the most likely scenario.

**Table 4.30: Number of animals predicted to experience behaviour disturbance under the maximum design piling scenarios.**

| Species | Model Location | Monopile (5,000 kJ) | | Pin Pile (2,500 kJ) | | Assessment | |
|---|---|---|---|---|---|---|---|
| | | # Animals | % MU | # Animals | % MU | Magnitude | Sensitivity |
| Harbour porpoise | NW | 6,471 | 1.87% | 5,359 | 1.55% | **Minor** | **Medium** |
| Minke whale | NW | 47 | 0.24% | 39 | 0.20% | **Negligible** | - |
| White-beaked dolphin | NW | 88 | 0.22% | 72 | 0.18% | **Negligible** | - |
| Harbour seal | S | 49 | 0.85% | 35 | 0.60% | **Negligible** | - |
| Grey seal | NW | 900 | 1.96% | 725 | 1.58% | **Minor** | **Low** |

### TTS from piling noise (MM-C-3).

4.11.1.54 Full details of the underwater noise modelling and the resulting TTS impact areas and ranges are detailed in **Volume 4, Annex 4.5: Subsea Noise Technical Report**. As outlined in **Section 4.10.3**, there are no thresholds to determine a biologically significant effect from TTS, therefore no assessment of the number of animals, magnitude, sensitivity or significance of effect is given. This approach was agreed with Consultees at Evidence Plan Technical Meeting 4 (30 April 2019).

### Vessel collision risk (MM-C-4).

4.11.1.55 The area surrounding Hornsea Four already experiences a reasonable amount of vessel traffic throughout the year, with an average of 16 vessels per day passing through the array area (see **Volume 2, Chapter 7: Shipping and Navigation**). Therefore, the introduction of additional vessels during construction is not a novel impact for marine mammals present in the area.

4.11.1.56 During construction of the wind farm, a potential source of impact from increased vessel activity is physical trauma from collision with a boat or ship. These injuries include blunt trauma to the body or injuries consistent with propeller strikes. The risk of collision of marine mammals with vessels would be directly influenced by the type of vessel and the speed with which it is travelling (Laist *et al.* 2001) and indirectly by ambient noise levels underwater and the behaviour the marine mammal is engaged in.

4.11.1.57 There is currently a lack of information on the frequency of occurrence of vessel collisions as a source of marine mammal mortality. There is little evidence from marine mammals stranded in the UK that injury from vessel collisions is an important source of mortality. The UK Cetacean Strandings Investigation Programme (CSIP) documents the annual number of reported strandings and the cause of death for those individuals examined at post mortem. **Table 4.31** outlines the number of strandings for each species, how many were examined at post mortem and how many concluded vessel collision as the cause of death between 2005 and 2015. The CSIP data shows that very few strandings have been attributed to vessel collisions, therefore, while there is evidence that mortality from vessel collisions can and does occur, it is not considered to be a key source of mortality highlighted from post mortem examinations.

**Table 4.31: Data from the UK Cetacean Strandings Investigation Programme (CSIP)[6] on the number of cetacean strandings and identified causes of death.**

| Species | Period | # Stranded | # Post-mortems | Vessel collision | Unknown physical trauma |
|---|---|---|---|---|---|
| Harbour Porpoise | 2011-2015 | 1676 | 371 | 13 | 23 |
| | 2005-2010 | 1922 | 478 | 4 | 22 |
| Minke Whale | 2011-2015 | 75 | 16 | 2 | 0 |
| | 2005-2010 | 87 | 11 | 1 | 0 |
| White-beaked dolphin | 2011-2015 | 79 | 33 | 0 | 1 |
| | 2005-2010 | 70 | 23 | 0 | 0 |

4.11.1.58 There are very few studies that indicate a critical level of activity in relation to risk of collisions but an analysis presented in Heinänen and Skov (2015) suggested that harbour porpoise density was significantly lower in areas with vessel transit rates of greater than 80 per day within a 5 km grid. As outlined in **Volume 1, Chapter 4: Project Description**, the busiest period during construction in terms of vessel traffic would be when up to eight vessels are present in a given 5 $km^2$ block. This level of activity is unlikely to occur across the entire Hornsea Four array area at any one time, rather this intensity is expected across approximately three or four 5 $km^2$ blocks. Vessel traffic in the Hornsea Four area, even

[6] (CSIP 2011, 2012, 2013, 2014, 2015, 2016)

considering the addition of construction traffic, will still be below 80 per day within a 5 km grid.

4.11.1.59 Harbour porpoises, dolphins and seals are relatively small and highly mobile, and given observed responses to noise, are expected to detect vessels in close proximity and largely avoid collision. Predictability of vessel movement by marine mammals is known to be a key aspect in minimising the potential risks imposed by vessel traffic (e.g. Nowacek *et al.* 2001, Lusseau 2003, 2006). The vessel management plan (Commitment Co108 of **Volume 4, Annex 5.2**) will ensure that vessel traffic moves along predictable routes and will define how vessels should behave in the presence of marine mammals.

4.11.1.60 It is highly likely that a proportion of vessels will be stationary or slow moving throughout construction activities for significant periods of time. Therefore, the actual increase in vessel traffic (see **Table 4.10**) moving around the site and to/from port to the site will occur over short periods of the offshore construction activity.

*Magnitude of impact*

4.11.1.61 It is not expected that the level of vessel activity during construction would cause an increase in the risk of mortality from collisions. The adoption of a vessel management plan during construction (Commitment Co108 of **Volume 4, Annex 5.2**) will minimise the potential for any impact. The impact is therefore predicted to be of local spatial extent, short term duration and intermittent. The magnitude is therefore considered to be **minor**.

*Sensitivity of the receptor*

4.11.1.62 All marine mammal receptors are deemed to be of low vulnerability given that vessel collision is not considered to be a key source of mortality highlighted from post mortem examinations of stranded animals. However, should a collision event occur, this is likely to injure the animal, from which they may have limited ability to recover from. As a result of the low vulnerability to a strike but the serious consequences of a strike, the sensitivity of the marine mammal receptors to collisions is considered to be **medium**.

*Significance of the effect*

4.11.1.63 Overall, the sensitivity of all marine mammals to vessel collisions has been assessed as **medium** and the magnitude is predicted to be **minor**. Therefore the effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.1.64 None proposed beyond existing commitments (see of **Volume 4, Annex 5.2 Commitment Register)**.

### Disturbance from vessels (MM-C-5).

4.11.1.65 Increased vessel traffic during construction has the potential to result in disturbance of marine mammals. Disturbance from vessel noise is only likely to occur where increased noise from vessel movements associated with the construction of the Development is greater than the background ambient noise. The maximum design scenario (**Table 4.10**) lists the maximum number of vessels that will be involved in construction. As outlined in **Volume 1, Chapter 4: Project Description**, the busiest period during construction in terms of vessel traffic would be when up to eight vessels are present in a given 5 $km^2$ block. This level of activity is unlikely to occur across the entire Hornsea Four array area at any one time, rather this intensity is expected across approximately three or four 5 $km^2$ blocks. The total duration of the installation campaign for turbines is expected to be a maximum of 12 months.

4.11.1.66 During the period of piling operations, it is considered unlikely that vessel noise will impact marine mammal receptors at levels additional to the piling activity itself. It is difficult to separate out the effect of vessel presence and activity from the effect of pile driving in isolation, since the data collected to date on the response of animals to pile driving, will have included a degree of vessel activity in combination with the piling, therefore it could be considered that the typical vessel activity related to pile driving, may be already assessed to some extent under the pile driving assessment. Individuals have more potential to be impacted by increased vessel movements during periods when piling is not taking place.

4.11.1.67 The magnitude and characteristics of vessel noise varies depending on ship type, ship size, mode of propulsion, operational factors and speed. Vessels of varying size produce different frequencies, generally becoming lower frequency with increasing size. The distance at which animals may react is difficult to predict and behavioural responses can vary a great deal depending on context.

*Magnitude of impact*

4.11.1.68 It is not expected that the level of vessel activity during the construction of Hornsea Four would cause a significant increase in the risk of disturbance by vessels. The adoption of a vessel management plan (Commitment Co108 of **Volume 4, Annex 5.2**) that includes preferred transit routes and guidance for vessel operations in the vicinity of marine mammals and around seal haul-outs will minimise the potential for any impact. The impact is predicted to be of local, short term duration and intermittent. It is expected that any marine mammals that are disturbed as a result of vessel presence will return to the area once the vessel disturbance has ended. The magnitude is therefore considered to be **minor**.

*Sensitivity of the receptor*

4.11.1.69 All marine mammal receptors are deemed to be of low vulnerability given the existing evidence behavioural responses to vessels (see **paragraph 4.10.4.29** onwards). The sensitivity of the marine mammal receptors is therefore considered to be **low**.

*Significance of the effect*

4.11.1.70 Overall, the sensitivity of marine mammals to vessel disturbance has been assessed as **low** and the magnitude is predicted to be **minor**. The effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.1.71 None proposed beyond existing commitments.

### Non-piling noise - Underwater noise from seabed preparation, rock dumping and cable installation (MM-C-9).

4.11.1.72 While impact piling will be the maximum design noise source during the construction phase, there will also be several other construction activities that will produce underwater noise. These include dredging, drilling, cable laying, rock placement and trenching (vessel noise is assessed separately above).

4.11.1.73 A simple assessment of the noise impacts from non-piling noise is presented in **Volume 4, Annex 4.5: Subsea Noise Technical Report**. Using the non-impulsive weighted $SEL_{cum}$ PTS and TTS thresholds from Southall *et al.* (2019) resulted in estimated PTS and TTS impact ranges of <100 m for all marine mammals species for each non-piling construction activity. These values mean that animals would have to stay within these very small ranges for 24 hours before they experienced injury, which is an extremely unlikely scenario as it is far more likely that any marine mammal within the injury zone would move away from the vicinity of the vessel and the construction activity.

4.11.1.74 The potential effects of cabling techniques used in the offshore wind farm industry was reviewed in a report by BERR in association with DEFRA (BERR and DEFRA 2008). The report reviewed various cable types and installation methods including burial ploughs, machines, ROVs and sleds and the burial methods themselves including jetting, rock ripping, and dredging. The review concluded that it would be "*highly unlikely that cable installation would produce noise at a level that would cause a behavioural reaction in marine mammals*".

4.11.1.75 There is evidence that bottlenose dolphins avoid areas when high levels of dredging activity occur, however this effect was only temporary (Pirotta *et al.* 2013). Therefore, any potential displacement as a result of dredging activities will be temporary and therefore unlikely to significantly affect marine mammal vital rates.

4.11.1.76 It is also highly likely that the presence of vessels will act as a deterrent and disturb marine mammals out of the area before any non-piling construction activity begins (as has been documented for harbour porpoise, Brandt *et al.* 2018).

*Magnitude of impact*

4.11.1.77 The assessment of behavioural disturbance from piling noise resulted in not significant impact to any marine mammal species. Since the underwater noise impacts from non-piling noise will be less than that of impact piling, this impact pathway is also assessed as not significant. The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect all marine mammal receptors directly. The underwater noise impacts from non-piling noise will be significantly less than that of impact piling, and will be very local and short term. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

**Reduction in prey availability (MM-C-6).**

4.11.1.78 Given that marine mammals are dependent on fish prey, there is the potential for indirect effects on marine mammals as a result of impacts upon fish species or the habitats that support them. The key prey species for each marine mammal receptor are listed in **Table 4.32**.

**Table 4.32: Common prey species for each of the marine mammal receptors. Key species are in bold.**

| Receptor | Prey species | References |
|---|---|---|
| Harbour porpoise | **Whiting, sandeel**<br>herring, haddock, saith, pollock, bobtail squid | Pierce *et al.* (2007) |
| Minke whale | **Sandeel, herring, sprat**<br>mackerel, goby, Norway pout/poor cod | Pierce *et al.* (2004) |
| White-beaked dolphin | **Haddock, whiting**<br>cod, herring, mackerel | Canning *et al.* (2008) |
| Harbour seal | **Sandeel**, **whiting**, **dragonet**<br>cod, herring, sprat, dover sole, plaice, lemon sole, dab, flounder, goby, bullrout, sea scorpion, octopus, squid | Wilson and Hammond (2016)<br>SCOS (2017) |
| Grey seal | **Sandeel**<br>cod, whiting, haddock, ling, plaice, sole, flounder, dab | SCOS (2017) |

4.11.1.79 **Volume 2, Chapter 4: Fish and Shellfish Ecology** concluded no significant impacts on all fish species except for herring, for which there was a moderate adverse impact but only in relation to pile driving at the HVAC site as it is located within a key herring spawning and nursery habitat. It is expected that adult spawning herring within these habitats would be affected and that there will be a moderate degree of disturbance at a near field distance predicted on herring eggs and larvae. However this disturbance would be very short term (days) given the number of OSS and piles required.

4.11.1.80 Herring has been identified as one of the key prey species for minke whales and is also a component of the diet of harbour porpoise, white-beaked dolphins and harbour seals (**Table 4.32**). While there may be certain species that comprise the main part of their diet, all marine mammals in this assessment are considered to be generalist feeders and are thus not reliant on a single prey species. Herring is not the largest component in the diet of any of the marine mammal species assessed. Therefore, the predicted impacts on the herring population at the spawning grounds at the HVAC site is unlikely to result in any significant effect on the probability of survival or on fertility rates for any marine mammal species as they are expected to be able to adapt by targeting other foraging areas and other prey species to compensate for any reduction in herring availability. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

### Reduction in foraging ability (MM-C-7).

4.11.1.81 Disturbance to water quality as a result of construction activities can have both direct and indirect impacts on marine mammals. Indirect impacts would include effects on prey species which have already been covered in the previous section. Direct impacts include the impairment of visibility and therefore foraging ability which might be expected to reduce foraging success. Marine mammals are well known to forage in tidal areas where water conditions are turbid and visibility conditions poor. For example, harbour porpoise and harbour seals in the UK have been documented foraging in areas with high tidal flows (e.g. Pierpoint 2008, Marubini *et al.* 2009, Hastie *et al.* 2016); therefore, low light levels, turbid waters and suspended sediments are unlikely to negatively impact marine mammal foraging success. It is important to note that it is hearing, not vision that is the primary sensory modality for most marine mammals. When the visual sensory systems of marine mammals are compromised, they are able to sense the environment in other ways, for example, seals can detect water movements and hydrodynamic trails with their mystacial vibrissae; while odontocetes primarily use echolocation to navigate and find food in darkness.

4.11.1.82 **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes** concluded that the magnitude of the maximum potential increase in Suspended Sediment Concentrations (SSC) resulting from construction activities is within the natural range of SSC (due to the naturally dynamic environment) within the region and the impact will be short-term, intermittent and of localised extent (within one tidal excursion) and reversible. Therefore, there is expected to be no significant increase in the level of SSC from the construction of Hornsea Four. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

### PTS from UXO clearance (MM-C-11).

4.11.1.83 There is the potential requirement for underwater UXO clearance prior to construction. However, since a UXO survey has not yet been conducted, it is not possible at this time to define an accurate prediction of the number of UXO which may require detonation. As a result, a separate Marine Licence will be applied for pre-construction for the detonation of any UXO. However, the detonation of UXO is a source of additional noise in the marine environment and hence is considered in the assessment for marine mammals. For this assessment, it has been assumed that a total of 86 targets will require detonation over a period of 150 to 324 days (depending on the number of targets per day)[7]. UXO clearance for

[7] Numbers are scaled are from the report: "HOW03 Estimation of Potential UXO – Main Array and Export Cable (V1.0)".

the purposes of this assessment is considered to involve the high-order detonation of the UXO in situ to make it safe to undertake construction works in the surrounding area.

4.11.1.84 Current advice from the statutory nature conservation bodies (SNCBs) is that the recent NOAA/Southall injury thresholds (NMFS 2018, Southall *et al.* 2019) should be used for assessing the impacts from UXO detonation on marine mammals. However, the suitability of the NOAA criteria for UXO is under discussion due to the lack of empirical evidence from UXO detonations using the NOAA metrics, in particular the range dependent characteristics of the peak sounds, and whether current propagation models can accurately predict the range at which these thresholds are reached. No noise modelling has been conducted for UXO clearance for Hornsea Four, and current models have not been validated at ranges relevant to the predictions and there is a possibility that models significantly overestimate ranges for large charge masses (>25 kg; von Benda-Beckmann *et al.* 2015). Therefore, a range of potential PTS impacts have been presented, based on data collated from previous studies:

- von Benda-Beckmann *et al.* (2015) reported that for a 263 kg charge weight at 28 m depth, based on values of overpressure levels that would lead to ear trauma from Ketten (2004), PTS for harbour porpoise could extend out to 1.8 km from the source, affecting an area of 10.18 km$^2$. In the absence of modelled results for other species using the same threshold, this has been assumed to apply across white-beaked dolphin, minke whales and seals;
- Beatrice Offshore Wind Farm in the Moray Firth also undertook noise modelling of UXO for a 50 kg explosive using the Southall *et al.* (2007) and NOAA thresholds (BOWL 2016). The BOWL modelling predicted PTS ranges of 225 m (0.16 km$^2$) for cetaceans and 764 m (1.83 km$^2$) for pinnipeds using Southall *et al.* (2007). Based on the NOAA thresholds, PTS ranges were 3.9 km (47.73 km$^2$) for harbour porpoise, 690 m (2.99 km$^2$) for minke whales and the same as Southall for white-beaked dolphins and seals;
- The noise modelling for Hornsea Project One of a 227 kg charge weight predicted PTS ranges (based on NOAA thresholds) of 8.2 km (211.24 km$^2$) for harbour porpoise, 550 m (0.95 km$^2$) for white-beaked dolphin, 1.66 km (8.66 km$^2$) for minke whale and 1.83 km (10.52 km$^2$) for pinnipeds. Modelling for a 260 kg UXO was also undertaken for harbour porpoise using the NOAA criteria which gave a range of 8.5 km (226.98 km$^2$).

4.11.1.85 The number of each species of marine mammal that could potentially be affected by PTS from UXO clearance for a range of charge sizes is presented in **Table 4.33**. This is quantified by calculating the numbers of animals likely to be within each of the stated impact ranges by multiplying the area of the impact range by the appropriate density estimate. Due to the lack of site-specific information at the current stage of the assessment, the variation in the range of impact ranges under consideration, and that fact that this assessment will be updated using more detailed UXO survey data prior to construction, it was deemed appropriate to adopt average uniform densities at the broadest spatial scale in this assessment. The SCANS III densities were therefore used for cetaceans, and the seal usage maps used for seals (assuming the UXO was located in the centre of the array area).

**Table 4.33: Estimated number of marine mammals potentially at risk of PTS during UXO clearance.**

| Species | UXO Data Source | Range (km) | Area ($km^2$) | # Impacted | % MU | Magnitude |
|---|---|---|---|---|---|---|
| Harbour porpoise (0.888 porpoise/$km^2$) | 263 kg charge weight von Benda-Beckman *et al.* (2015) | 1.8 | 10.18 | 9 | 0.003% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of Southall *et al.* (2007) | 0.225 | 0.16 | <1 | 0.000% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of NOAA | 3.9 | 47.73 | 42 | 0.012% | **Negligible** |
| | 260 kg charge weight Hornsea Project One modelling using NOAA | 8.5 | 226.98 | 202 | 0.058% | **Minor** |
| Minke whale (0.010 whales/$km^2$) | 263 kg charge weight von Benda-Beckman *et al.* (2015) | 1.8 | 10.18 | <1 | 0.000% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of Southall *et al.* (2007) | 0.225 | 0.16 | <1 | 0.000% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of NOAA | 0.690 | 2.99 | <1 | 0.000% | **Negligible** |
| | 227 kg charge weight Hornsea Project One modelling NOAA thresholds | 1.66 | 8.66 | <1 | 0.000% | **Negligible** |
| White-beaked dolphin (0.002 dolphins/$km^2$) | 263 kg charge weight von Benda-Beckman *et al.* (2015) | 1.8 | 10.18 | <1 | 0.000% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of Southall *et al.* (2007) | 0.225 | 0.16 | <1 | 0.000% | **Negligible** |
| | 227 kg charge weight Hornsea Project One modelling NOAA thresholds | 1.66 | 8.66 | <1 | 0.000% | **Negligible** |
| Harbour seal (grid cell specific densities) | 263 kg charge weight von Benda-Beckman *et al.* (2015) | 1.8 | 10.18 | <1 | 0.005% | **Negligible** |
| | 50 kg charge weight | 0.764 | 1.83 | <1 | 0.000% | **Negligible** |

| Species | UXO Data Source | Range (km) | Area ($km^2$) | # Impacted | % MU | Magnitude |
|---|---|---|---|---|---|---|
| | BOWL (2016) modelling of Southall *et al.* (2007) | | | | | |
| | 227 kg charge weight Hornsea Project One modelling NOAA thresholds | 1.83 | 10.52 | <1 | 0.005% | **Negligible** |
| Grey seal (grid cell specific densities) | 263 kg charge weight von Benda-Beckman *et al.* (2015) | 1.8 | 10.18 | 2 | 0.003% | **Negligible** |
| | 50 kg charge weight BOWL (2016) modelling of Southall *et al.* (2007) | 0.764 | 1.83 | <1 | 0.000% | **Negligible** |
| | 227 kg charge weight Hornsea Project One modelling NOAA thresholds | 1.83 | 10.52 | 2 | 0.003% | **Negligible** |

*Magnitude of impact*

4.11.1.86 The impact is predicted to be of local spatial extent, short term duration and intermittent, however since PTS is a permanent change in the hearing threshold, it is not recoverable. Hornsea Four will be required to implement a UXO specific MMMP to ensure that the risk of PTS is reduced to negligible. The exact mitigation measures contained with the UXO MMMP are yet to be determined and will be agreed with Natural England and the MMO. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

### Disturbance from UXO clearance (MM-C-12).

4.11.1.87 Natural England and JNCC advise that a buffer of 26 km around the source location is used to determine the impact area from UXO clearance with respect to disturbance of harbour porpoise in the Southern North Sea SAC. In the absence of agreed metrics for the use of other marine mammal species for disturbance and given a lack of empirical data on the likelihood of response to explosives, this 26 km radius (area of 2,124 $km^2$) has been applied for all species. The resulting number of animals, proportion of the reference population and impact magnitude is detailed in **Table 4.34**. This is quantified by calculating the numbers of animals likely to be within each of the stated impact ranges by multiplying the area of the impact range by the appropriate density estimate. Due to the lack of site-specific information at the current stage of the assessment, the variation in the range of impact ranges under consideration, and that fact that this assessment will be updated using more detailed UXO survey data prior to construction, it was deemed appropriate to adopt average uniform densities at the broadest spatial scale in this assessment. The SCANS III densities were therefore used for cetaceans, and the seal usage maps used for seals (assuming the UXO was located in the centre of the array area).

**Table 4.34: Estimated number of marine mammals potentially at risk of disturbance during UXO clearance (assuming UXO is located at the centre of the array area).**

| Species | Density Source | Density (#/km$^2$) | # Impacted | % Ref Pop | Magnitude |
|---|---|---|---|---|---|
| Harbour porpoise | SCANS-III Block O | 0.888 | 1,886 | 0.55% | **Negligible** |
| Minke whale | SCANS-III Block O | 0.010 | 21 | 0.11% | **Negligible** |
| White-beaked dolphin | SCANS-III Block O | 0.002 | 4 | 0.01% | **Negligible** |
| Harbour seal | At-sea usage | Grid cell specific | 46 | 0.79% | **Negligible** |
| Grey seal | At-sea usage | Grid cell specific | 391 | 0.85% | **Negligible** |

*Magnitude of impact*

4.11.1.88 The impact is predicted to be of local spatial extent, very short term duration, intermittent and high reversibility. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

### 4.11.2 Operation and Maintenance

4.11.2.1 The impacts of the offshore operation and maintenance of Hornsea Four have been assessed on marine mammals. The environmental impacts arising from the operation and maintenance of Hornsea Four are listed in **Table 4.10** along with the maximum design scenario against which each operation and maintenance phase impact has been assessed.

### Operational noise (MM-O-14).

4.11.2.2 Operational WTGs will produce underwater noise a result of vibration from the rotating machinery in the turbines, which is transmitted through the structure of the pile and foundations. An assessment was made based on an extrapolation from measured data from operational offshore wind farms sites with smaller sizes rotors (see **Volume 4, Annex 4.5: Subsea Noise Technical Report**). By applying a linear fit to the existing data, and extrapolating to a rotor diameter of 305 m, the estimated source level at Hornsea Four is 165.4 dB SPL (RMS) @ 1 m. Using the non-impulsive weighted $SEL_{cum}$ PTS and TTS thresholds from Southall *et al.* (2019) resulted in estimated PTS and TTS impact ranges of <100 m for all marine mammals species.

4.11.2.3 The MMO (2014) review of post-consent monitoring at offshore wind farms found that available data on the operational WTG noise, from the UK and abroad, in general showed that noise levels from operational WTGs are low and the spatial extent of the potential impact of the operational WTG noise on marine receptors is generally estimated to be small, with behavioural response only likely at ranges close to the WTG. This is supported by several published studies which provide evidence that marine mammals are not displaced from operational wind farms.

4.11.2.4 At the Horns Rev and Nysted offshore wind farms in Denmark, long-term monitoring showed that both harbour porpoise and harbour seals were sighted regularly within the operational offshore windfarms, and within two years of operation, the populations had returned to levels that were comparable with the wider area (Diederichs *et al.* 2008). Similarly, a monitoring programme at the Egmond aan Zee Offshore Windfarm in the Netherlands reported that significantly more porpoise activity was recorded within the wind farm compared to the reference area during the operational phase (Scheidat *et al.* 2011). Other studies at Dutch and Danish offshore wind farms (e.g. Lindeboom *et al.* 2011) also suggest that harbour porpoise may be attracted to increased foraging opportunities within operating offshore wind farms. In addition, recent tagging work by Russell *et al.* (2014) found that some tagged harbour and grey seals demonstrated grid-like movement patterns as these animals moved between individual WTGs, strongly suggestive of these structures providing enhanced or novel foraging opportunities.

4.11.2.5 Other reviews have also concluded that operational wind farm noise will have negligible effects (Madsen *et al.* 2006, Teilmann *et al.* 2006, CEFAS 2010, Brasseur *et al.* 2012). In addition studies have shown that porpoise are detected regularly within operational offshore wind farms (Diederichs *et al.* 2008, Scheidat *et al.* 2011) and may be attracted to offshore wind farms for increased foraging opportunities (Lindeboom *et al.* 2011).

*Magnitude of impact*

4.11.2.6 The impact of operational noise is predicted to be of limited local extent, long term duration and continuous. The magnitude is therefore, considered to be **minor**.

*Sensitivity of the receptor*

4.11.2.7 Given the evidence of their presence in and around existing operational offshore wind farms, marine mammals are deemed to be of low vulnerability and have high recoverability to the impact of operational noise. The sensitivity of all marine mammal receptors is therefore, considered to be **low**.

*Significance of the effect*

4.11.2.8 Overall, the sensitivity of marine mammals to operational noise has been assessed as **low** and the magnitude is predicted to be **minor**. The effect is **not significant** in EIA terms.

*Further mitigation*

4.11.2.9 None proposed beyond existing commitments.

### Vessel collision risk (MM-O-28).

4.11.2.10 The MDS states that there will be a maximum of 3,525 return visits per year during the operation and maintenance of Hornsea Four. This equates to an average of approximately 10 return trips per day; however, it is expected that a currently unknown portion of these will be by helicopter rather than by vessel. Vessel types will include crew transport vessels (CTVs), service operation vessels (SOVs), supply vessels, cable and remedial protection vessels and jack-up vessels (JUVs).

4.11.2.11 There are very few studies that indicate a critical level of activity in relation to risk of collisions but an analysis presented in Heinänen and Skov (2015) suggested that harbour porpoise density was significantly lower in areas with vessel transit rates of greater than 80 per day. Vessel traffic in the Hornsea Four area, even considering the addition of operation and maintenance traffic will still be well below this figure.

*Magnitude of impact*

4.11.2.12 It is not expected that the level of vessel activity during the operation and maintenance of Hornsea Four would cause an increase in the risk of mortality from collisions. The adoption of a vessel management plan (Co108).

4.11.2.13

4.11.2.14 Table 4.9 and Volume 4, Annex 5.2: Commitments Register) that includes preferred transit routes and guidance for vessel operations in the vicinity of marine mammals and around seal haul-outs will minimise the potential for any impact. The impact is predicted to be of local, short term duration and intermittent. The magnitude is therefore considered to be **minor**.

*Sensitivity of the receptor*

4.11.2.15 All marine mammal receptors are deemed to be of low vulnerability given the existing evidence on collision related mortality in the strandings data (see paragraph 4.11.1.57 onwards), however there is the potential for vessel collisions to cause injury or mortality to marine mammals. The low vulnerability to collisions combined with the potential for injury or mortality leads to a sensitivity of **medium**.

*Significance of the effect*

4.11.2.16 Overall, the sensitivity of marine mammals to vessel collision risk has been assessed as **medium** and the magnitude is predicted to be **minor**. The effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.2.17 None proposed beyond existing commitments.

### Disturbance from vessels (MM-O-15).

4.11.2.18 The MDS states that there will be a maximum of 3,525 return visits per year during the operation and maintenance of Hornsea Four, however, it is expected that a currently unknown portion of these will be by helicopter rather than by vessel. Vessel types will include CTVs, SOVs, supply vessels, cable and remedial protection vessels and JUVs.

*Magnitude of impact*

4.11.2.19 It is not expected that the level of vessel activity during the operation and maintenance of Hornsea Four would cause a significant increase in the risk of disturbance by vessels. The adoption of a vessel management plan that includes preferred transit routes and guidance for vessel operations in the vicinity of marine mammals and around seal haul-outs will minimise the potential for any impact. The impact is predicted to be of local, short term duration and intermittent. It is expected that any marine mammals that are disturbed as a result of vessel presence will return to the area once the vessel disturbance has ended. The magnitude is therefore considered to be **minor**.

*Sensitivity of the receptor*

4.11.2.20 All marine mammal receptors are deemed to be of low vulnerability given the existing evidence behavioural responses to vessels (see **paragraph 4.10.4.29** onwards). The sensitivity of the marine mammal receptors is therefore considered to be **low**.

*Significance of the effect*

4.11.2.21 Overall, the sensitivity of marine mammals has been assessed as **low** and the magnitude is predicted to be **minor**. The effect is of **minor** adverse significance, which is not significant in EIA terms.

*Further mitigation*

4.11.2.22 None proposed beyond existing commitments.

**Reduction in prey availability (MM-O-16).**

4.11.2.23 It is possible that operational wind farms may actually increase prey availability. Tagged seals have shown targeted foraging behaviour around operational offshore wind farms which suggests that they act as fish aggregating devices, providing enhanced or novel foraging opportunities (Russell *et al.* 2014). In addition, studies have shown that porpoise are detected regularly within operational offshore wind farms (Diederichs *et al.* 2008, Scheidat *et al.* 2011) and may be attracted to offshore wind farms for increased foraging opportunities (Lindeboom *et al.* 2011). Therefore, it is possible that the underwater structures associated with Hornsea Four could provide an ecological benefit by providing new foraging opportunities to marine mammals in the area. Any potential habitat change as a result of fish aggregation or artificial reefs is expected to positively affect marine mammals by providing novel foraging opportunities.

4.11.2.24 **Volume 2, Chapter 3: Fish and Shellfish Ecology** concluded no significant impacts on any fish species during the operational phase of Hornsea Four. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

**Reduction in foraging ability (MM-O-17).**

4.11.2.25 Disturbance to water quality as a result of operation and maintenance activities can have both direct and indirect impacts on marine mammals. Indirect impacts would include effects on prey species which have already been covered in the previous section. Direct impacts include the impairment of visibility and therefore foraging ability which might be expected to reduce foraging success. As outlined above, marine mammals are known to frequent operational windfarms with evidence for potential feeding within arrays. The magnitude of this impact is therefore considered to be **negligible** and is not considered further in this assessment, as it will not lead to a significant effect based on the matrix used for the assessment of significance (**Figure 4.1**).

#### 4.11.3 Decommissioning

4.11.3.1 The impacts of the offshore decommissioning of Hornsea Four have been assessed on marine mammals. The environmental impacts arising from the decommissioning of Hornsea Four are listed in **Table 4.10** along with the MDS against which each decommissioning phase impact has been assessed. Decommissioning would involve the dismantling of structures and removal of offshore structures above the seabed, in reverse order to the construction sequence. The effects of these activities on marine mammals are considered to be similar to or less (as a result of there being no piling) than those occurring as a result of construction. Therefore, the effects of decommissioning are considered to be no greater than those described for the construction phase.

### PTS from underwater noise (MM-D-20).

4.11.3.2 Piled foundations would likely be cut approximately 1 m below the seabed, however the exact decommissioning methods have yet to be determined, and as such no quantitative assessment can be made at this stage. The Energy Act (2004) requires that a decommissioning plan must be submitted to and approved by the Secretary of State for Business, Energy and Industrial Strategy, a draft of which would be submitted prior to the construction of Hornsea Four. The decommissioning plan and programme will be updated during Hornsea Four's lifespan to take account of changing best practice and new technologies. The approach and methodologies employed at decommissioning will be compliant with the legislation and policy requirements at the time of decommissioning. It is assumed that the MDS is to be as per construction (with no pile driving), thus the impact is assumed to be similar to the construction phase (or less). The impact of PTS from decommissioning activities has therefore been assessed as either **not significant** (minke whales, white-beaked dolphin, harbour and grey seal) or **minor** significance (harbour porpoise) depending on the magnitude assessment, which is not significant in EIA terms. Hornsea Four has committed to develop a decommissioning MMMP in consultation with the MMO and Natural England which will include robust measures to ensure the risk of PTS to marine mammals is **negligible** (Co113 of **Volume 4, Annex 5.2**).

### Disturbance from underwater noise (MM-D-21).

4.11.3.3 There are very few examples of empirical data describing the source level of underwater cutting noise. One study found that sound radiated from a diamond wire cutting operation was not easily discernible above the background noise during cutting operations (Panjerc *et al.* 2016). Other forms of cutting (e.g. abrasive water jet cutting) are considered to be low impact (Brandon *et al.* 2000, Kaiser *et al.* 2005). Given the data available, it is highly unlikely that the noise generated by cutting to remove structures has the potential to disturb marine mammals. The impact is assumed to be similar to the construction phase (or less), therefore the impact of disturbance from underwater noise during decommissioning has been assessed as **minor** adverse significance, which is not significant in EIA terms.

### TTS from underwater noise (MM-D-22).

4.11.3.1 Impact assumed to be similar to the construction phase (or less). No assessment of the significance of TTS is provided.

### Vessel collision risk (MM-D-23).

4.11.3.2 The level of vessel activity during the decommissioning phase are predicted to be the same as for the construction period. Therefore, the impact is assumed to be similar to construction phase (or less). The impact of vessel collision risk during decommissioning has therefore been assessed as **minor** adverse significance, which is not significant in EIA terms.

### Disturbance from vessels (MM-D-24).

4.11.3.3 The level of vessel activity during the decommissioning phase are predicted to be the same as for the construction period. Therefore, the impact is assumed to be similar to construction phase (or less). The impact of vessel disturbance during decommissioning has therefore been assessed as **minor** adverse significance, which is not significant in EIA terms.

### Reduction in prey availability (MM-D-25).

4.11.3.4 **Volume 2, Chapter 3: Fish and Shellfish Ecology** concluded no significant impacts on any fish species during the decommissioning phase of Hornsea Four. The magnitude is therefore considered to be **negligible** adverse for marine mammals, and is not considered further in this assessment, as it will not lead to a significant effect.

### Reduction in foraging ability (MM-D-26).

4.11.3.5 Increases in SSC and sediment deposition from the decommissioning works will be similar to that for construction and are of a similar magnitude. There is expected to be no significant increase in the level of suspended sediment concentration from the construction of Hornsea Four, thus there is also expected to be no significant increase in the level of suspended sediment concentration from the decommissioning of Hornsea Four. The magnitude is therefore considered to be **negligible** adverse and is not considered further in this assessment, as it will not lead to a significant effect.

## 4.12 Cumulative effect assessment (CEA)

4.12.1.1 Cumulative effects can be defined as effects upon a single receptor from Hornsea Four when considered alongside other proposed and reasonably foreseeable projects and developments. This includes all projects that result in a comparative effect that is not intrinsically considered as part of the existing environment and is not limited to offshore wind projects.

4.12.1.2 A screening process has identified a number of reasonably foreseeable projects and developments which may act cumulatively with Hornsea Four. The full list of such projects that have been identified in relation to the offshore environment are set out in **Volume 4, Annex 5.3: Offshore Cumulative Effects** and are presented in a series of maps within **Volume 4, Annex 5.4: Location of Offshore Cumulative Schemes**.

4.12.1.3 In assessing the potential cumulative impacts for Hornsea Four, it is important to bear in mind that some projects, predominantly those 'proposed' or identified in development plans, may not actually be taken forward, or fully built out as described within their MDS. There is therefore a need to build in some consideration of certainty (or uncertainty) with respect to the potential impacts which might arise from such proposals. For example, those projects under construction are likely to contribute to cumulative impacts (providing effect or spatial pathways exist), whereas those proposals not yet approved are less likely to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors.

4.12.1.4 With this in mind, all projects and plans considered alongside Hornsea Four have been allocated into 'tiers' reflecting their current stage within the planning and development process. This allows the cumulative impact assessment to present several future development scenarios, each with a differing potential for being ultimately built out. This approach also allows appropriate weight to be given to each scenario (tier) when considering the potential cumulative impact. The proposed tier structure that is intended to ensure that there is a clear understanding of the level of confidence in the cumulative assessments provided in the Hornsea Four PEIR. An explanation of each tier is included in **Table 4.35**.

4.12.1.5 The proposed tier structure for marine mammals is different to that presented for other receptors. This is due to the need to take into account greater levels of uncertainty in the degree and timing of overlap of activities which will generate significant levels of underwater noise during the construction phase of projects.

**Table 4.35: Description of tiers of other developments considered for CEA (adapted from PINS Advice Note 17).**

| | |
|---|---|
| Tier 1 | Operational and under construction projects which were not in place when baseline data was collected.<br>Projects with a legally secure consent (i.e. projects which are not on hold subject to an ongoing judicial review process) that have been awarded a Contract For Difference (CFD) but have not yet been implemented.<br>All Tier 1 offshore wind farm projects are due to be commissioned prior to the construction of the proposed Hornsea Four but will have an ongoing operational cumulative impact not considered part of the baseline. Therefore there is no potential for the overlap in the construction and pile driving of these projects with the pile driving at Hornsea Four.<br>All other Tier 1 projects that were operational or ongoing at the time of the baseline data collection have been screened out of the assessment. |
| Tier 2 | Tier 2 includes all projects/plans that have a legally secure consent but have no CFD therefore there is uncertainty about the timeline for construction of these projects.<br>Tier 2 offshore windfarms have the potential for cumulative operational and maintenance and decommissioning impacts. The potential for cumulative construction phase impacts have been considered where there is a reasonable chance of overlap of pile driving with Hornsea Four. |

| | |
|---|---|
| Tier 3 | Tier 3 projects are projects for which an application has been submitted, but not yet determined. There is therefore information on which to base a quantitative assessment of cumulative impact but there is a degree of uncertainty as to the final approved design of the project and the timeline for construction.<br>Tier 3 offshore wind farm projects have the potential for cumulative construction, operational and maintenance and decommissioning impacts. |
| Tier 4 | Tier 4 projects are relevant marine infrastructure projects that the regulatory body are expecting to be submitted for determination and for projects for which Preliminary Environmental Information Report (PEIR) has been submitted, but not a full ES yet submitted. There is therefore some information on which to base a quantitative assessment of cumulative impact but there is a large degree of uncertainty as to the final design of the project and the timeline for construction.<br>Tier 4 offshore wind farm projects have the potential for cumulative construction, operational and maintenance and decommissioning impacts. |
| Tier 5 | Tier 5 projects are relevant marine infrastructure projects that the regulatory body are expecting to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects). For tier 4 projects there is a lot of uncertainty and not enough information to allow a robust assessment. However, as a very precautionary approach, the Tier 5 UK offshore windfarm projects that we are currently aware of have been included in the CEA. |

4.12.1.6 The plans and projects selected as relevant to the CEA of impacts to marine mammals are based on an initial screening exercise undertaken on a long list (see **Volume 4, Annex 5.3: Offshore Cumulative Effects**). A consideration of effect-receptor-pathways, data confidence and temporal and spatial scales has been given to select projects for a topic-specific short-list. For the majority of potential effects for marine mammals, planned projects were screened into the assessment based on the extent of the relevant marine mammal reference population area for harbour porpoise (all cetaceans were based on the North Sea as the largest area over which cumulative effects could be realistically expected to overlap) and the grey seal (the combined Northeast and Southeast SMAs). Harbour seals have been scoped out of the CEA due to the extremely low levels of impact on this species from the project alone assessment.

4.12.1.7 The specific projects scoped into the CEA for marine mammals, as well as the tiers into which they have been allocated are presented in **Table 4.36** below and are illustrated in **Figure 4.5**:. The operational projects included within the table are included due to their completion/ commissioning subsequent to the data collection process for Hornsea Four and as such not included within the baseline characterisation. Note that this table only includes the projects screened into the assessment for marine mammals based on the criteria outlined above. For the full list of projects considered, including those screened-out, please see the Cumulative Effects Annex (**Volume 4, Annex 5.3: Offshore Cumulative Effects**).

**Table 4.36: Projects screened-in to the marine mammal cumulative assessment (HP = harbour porpoise, MW = minke whale, WBD = white-beaked dolphin, GS = grey seal).**

| Tier | Project/ plan | Details/ relevant dates | Distance to Hornsea Four Array (km) | Distance to Hornsea Four ECC (km) | Distance to Hornsea Four HVAC Booster Area | Reason for inclusion in CEA | Species |
|---|---|---|---|---|---|---|---|
| *Offshore wind farms* | | | | | | | |
| 1 | Hornsea Project Two | Under Construction: Commissioning expected 2023 | 0 | 6 | 66 | Operational cumulative impacts | all |
| 1 | Hornsea Project One | Under Construction: Commissioning expected 2020 | 5 | 21 | 83 | Operational cumulative impacts | all |
| 1 | Dudgeon | Operational | 71 | 73 | 102 | Operational cumulative impacts | HP, GS |
| 1 | Blyth | Operational | 179 | 141 | 158 | Decommissioning overlaps with Hornsea Four construction phase | all |
| 1 | East Anglia One | Under Construction: Commissioning expected 2021 | 194 | 199 | 237 | Operational cumulative impacts | HP, GS |
| 1 | Neart na Gaoithe | Consented: Construction expected 2020-2022 | 296 | 271 | 284 | Construction and Operational cumulative impacts | HP, MW WBD |
| 1 | Beatrice | Under Construction: Commissioning expected 2019 | >500 | 489 | 498 | Operational cumulative impacts | HP, MW WBD |
| 1 | Moray East | Under Construction: Commissioning expected 2021 | 494 | 484 | 492 | Operational cumulative impacts | HP, MW WBD |
| 1 | Borssele II | Consented: Construction expected 2019-2020 | 261 | 266 | 301 | Operational cumulative impacts | HP, GS |
| 1 | THV Mermaid | Consented: Construction expected 2019 | 261 | 265 | 300 | Operational cumulative impacts | HP, GS |
| 1 | Borkum Riffgrund II | Consented: Construction expected 2019-2020 | 313 | 333 | 393 | Operational cumulative impacts | HP, GS |

| Tier | Project/ plan | Details/ relevant dates | Distance to Hornsea Four Array (km) | Distance to Hornsea Four ECC (km) | Distance to Hornsea Four HVAC Booster Area | Reason for inclusion in CEA | Species |
|---|---|---|---|---|---|---|---|
| 1 | Borkum Riffgrund West II | Consented: Construction expected 2020-2021 | 291 | 310 | 370 | Operational cumulative impacts | HP, GS |
| 1 | Deutsche Bucht Pilot | Consented: Construction expected 2019 | 270 | 289 | 347 | Operational cumulative impacts | HP, GS |
| 1 | Triton Knoll | Consented: Construction expected 2019-2021 | 57 | 50 | 61 | Operational cumulative impacts | HP, GS |
| 2 | Dogger Bank Creyke Beck A | Consented: Construction expected 2021-2024 | 66 | 84 | 108 | Operational cumulative impacts | all |
| 2 | Dogger Bank Creyke Beck B | Consented: Construction expected 2021-2024 | 76 | 94 | 111 | Operational cumulative impacts | all |
| 2 | Sofia | Consented: Construction expected 2023-2026 | 98 | 113 | 143 | Construction and Operational cumulative impacts | all |
| 2 | Dogger Bank Teesside A | Consented: Construction expected 2023-2026 | 121 | 136 | 170 | Construction and Operational cumulative impacts | all |
| 2 | East Anglia Three | Consented: Construction expected 2020-2023 | 158 | 165 | 212 | Operational cumulative impacts | HP, GS |
| 2 | Inch Cape | Consented: Construction expected 2020-2022 | 312 | 291 | 303 | Operational cumulative impacts | HP, MW WBD |
| 2 | Seagreen Alpha | Consented: Construction expected 2020-2022 | 312 | 295 | 305 | Operational cumulative impacts | HP, MW WBD |
| 2 | Seagreen Bravo | Consented: Construction expected 2020-2022 | 312 | 295 | 305 | Operational cumulative impacts | HP, MW WBD |
| 3 | Hornsea Three | Application submitted: Construction expected 2024-post 2030 | 36 | 55 | 116 | Construction and Operational cumulative impacts | all |
| 3 | Norfolk Vanguard | Application submitted: Construction expected 2024-20208 | 123 | 131 | 176 | Construction and Operational cumulative impacts | HP, GS |
| 3 | Thanet Extension | Application submitted: Construction expected | 276 | 278 | 279 | Operational cumulative impacts | HP, GS |

| Tier | Project/ plan | Details/ relevant dates | Distance to Hornsea Four Array (km) | Distance to Hornsea Four ECC (km) | Distance to Hornsea Four HVAC Booster Area | Reason for inclusion in CEA | Species |
|---|---|---|---|---|---|---|---|
| | | 2021-2023 | | | | | |
| 3 | Moray West | Consented: Construction expected 2022-2024 | 491 | 478 | 487 | Operational cumulative impacts | HP |
| 4 | Norfolk Boreas | PEIR Submitted: Construction expected 2022-2025 | 123 | 134 | 187 | Construction and Operational cumulative impacts | HP, GS |
| 4 | East Anglia One North | PEIR Submitted: Construction expected 2025-2028 | 179 | 183 | 220 | Construction and Operational cumulative impacts | HP, GS |
| 4 | East Anglia Two | PEIR Submitted: Construction expected 2026-2029 | 187 | 191 | 224 | Construction and Operational cumulative impacts | HP, GS |
| *Cables and Pipelines* | | | | | | | |
| 1 | Viking Link | Consented: Construction expected 2020-2024 | 0 | 0 | 41 | Operational cumulative impacts | HP, GS |
| 1 | Hornsea Project Two Export Cables | Consented: Construction expected 2020-2021 | 0 | 9 | >50 | Operational cumulative impacts | all |
| 1 | Hornsea Project One Export Cables | Under Construction: completion expected 2019 | 12 | 22 | >50 | Operational cumulative impacts | all |
| 2 | Dogger Bank Creyke Beck A Export Cables | Consented: Construction expected 2021-2024 | 25 | 0 | 8 | Operational cumulative impacts | HP, GS |
| 2 | Dogger Bank Creyke Beck B Export Cables | Consented: Construction expected 2021-2024 | 25 | 0 | 8 | Operational cumulative impacts | all |
| *Other Activities* | | | | | | | |
| | *Seismic Surveys across various Oil and Gas development blocks in the North Sea* | *Ongoing* | | | | Construction and Operational cumulative impacts | all |

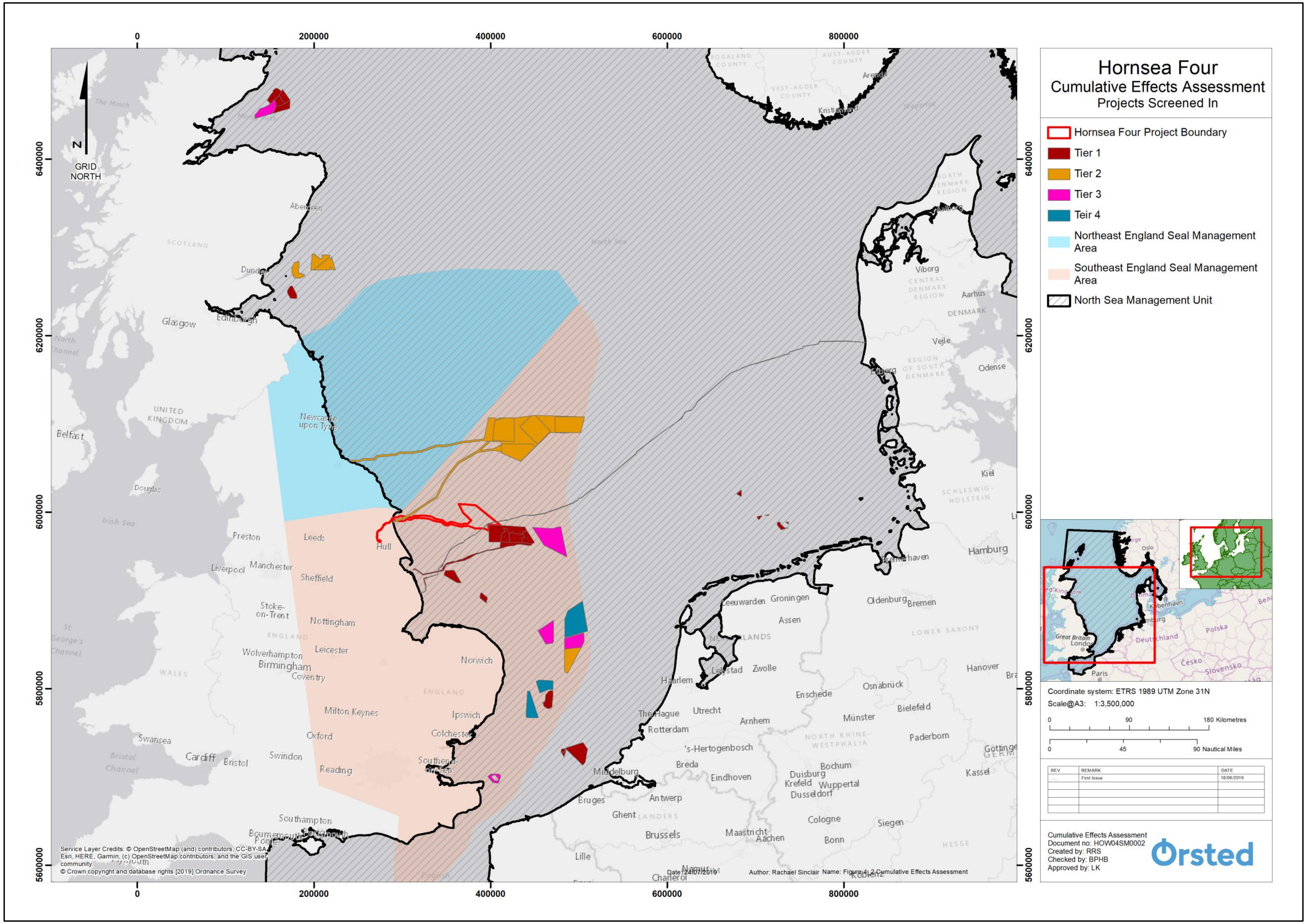


Figure 4.5: Projects screened-in to the Cumulative Effects Assessment for marine mammals (not to scale).

4.12.1.8 Certain impacts assessed for Hornsea Four alone are not considered in the cumulative assessment due to:

- The highly localised nature of the impacts (i.e. they occur entirely within the Hornsea Four boundary only);
- Management and mitigation measures in place for Hornsea Four will also be in place on other projects reducing their risk of occurring; and/or
- Where the potential significance of the impact from Hornsea Four alone has been assessed as negligible.

4.12.1.9 The impacts excluded from the CEA for the above reasons are:

- Auditory injury (PTS): where PTS may result from activities such as pile driving and UXO clearance, suitable mitigation will be put in place to reduce injury risk to marine mammals to negligible levels (as a requirement of European Protected Species legislation);
- Disturbance from underwater noise during construction to minke whale, white beaked dolphin and harbour seals due to the negligible levels predicted for these species in the project alone assessment;
- Changes in prey availability during construction and operation; and
- Operational noise: not included for any species due to localised effects and an assessment of negligible significance in the project alone assessment.

4.12.1.10 Therefore, the impacts that are considered in the CEA are as follows:

- The potential for disturbance to harbour porpoise and grey seals from underwater noise during construction activity (pile driving, UXO, seismic survey, vessels, other construction activity);
- Collision risk from vessels during construction and operation; and
- Disturbance from underwater noise from vessels during operation.

4.12.1.11 The cumulative MDS described in **Table 4.37** have been selected as those having the potential to result in the greatest cumulative effect on an identified receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the project description for Hornsea Four (summarised for marine mammals in **Table 4.10**), as well as the information available on other projects and plans in order to inform a cumulative maximum design scenario. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project design envelope to that assessed here, be taken forward in the final design scheme.

**Table 4.37: Cumulative MDS for marine mammals.**

| Project Phase | Potential Impact | Maximum Design Scenario | Justification |
|---|---|---|---|
| Construction | Cumulative effect of underwater noise from Hornsea Four construction operations alongside other underwater noise generating activities (construction activities including vessel activity, piling operations, UXO clearance and seismic survey activity). | Maximum design scenario for Hornsea Four (maximum design) plus the cumulative construction activities of the following projects (piling and UXO clearance activities):<br>**Tier 1:**<br>Decommissioning activities at Blyth Offshore Wind Farm<br>**Tier 2:**<br>All Tier 1 projects as well as the construction and UXO clearance activities at offshore wind farm projects consented but not yet under construction (Sofia; Dogger Bank Teeside A)<br>**Tier 3:**<br>All Tier 2 projects plus construction and UXO clearance activities at offshore wind farm projects that have been submitted but not yet determined (Hornsea Three; Norfolk Vanguard)<br>**Tier 4:**<br>Construction and UXO clearance activities at offshore wind farm projects where full applications have not yet been submitted (Norfolk Boreas; East Anglia One North; East Anglia Two).<br><br>In addition to underwater noise generated by seismic surveys. | Maximum potential for cumulative effects from underwater noise associated with offshore wind farm construction and other noisy activities is considered within the relevant management unit/area for each species. This spatial scale was chosen as a result of the spatial extent of noise related impacts as well as the high mobility of marine mammal receptors.<br>Only projects where the construction periods are expected to overlap with, or occur immediately prior to or after, the construction activity at Hornsea Four have been included. |
| Operation | Cumulative effect of underwater noise disturbance from an increase in vessel activity across the operational phase of Hornsea Four alongside other operations requiring an increase in vessel activity. | Maximum design scenario for Hornsea Four plus the cumulative operational activities of the following projects:<br>**Tier 1:**<br>Vessels associated with offshore wind farm projects under construction and expected to be commissioned before the construction of Hornsea Four (Hornsea Project One, Hornsea Project Two, East Anglia One, Neart na Gaoithe, Moray East, Beatrice, Triton Knoll, Borssele II, THV Mermaid, Borkum Riffgrund II, Borkum Riffgrund West II, Deutche Bucht Pilot)<br>**Tier 2:**<br>Vessels associated with offshore wind farm projects consented but not yet under construction but which are expected to be operational at the same time as | Maximum potential for cumulative effects from underwater noise associated with vessel activity is considered within the relevant management unit/area for each species. This spatial scale was chosen as a result of the high mobility of marine mammal receptors.<br>Projects where there is potential for the operational periods to overlap with the operational period of Hornsea Four are included. |

| Project Phase | Potential Impact | Maximum Design Scenario | Justification |
|---|---|---|---|
| | | Hornsea Four (Sofia, Dogger Bank Teeside A, Dogger Bank Creyke Bank A &B, East Anglia Three, Inch Cape, Seagreen Alpha and Bravo, Moray West)<br>**Tier 3:**<br>Vessel activity associated with operation of activities at offshore wind farm projects that have been submitted but not yet determined (Hornsea Three; Norfolk Vanguard, Thanet Extension) that may be operational at the same time as Hornsea Four.<br>**Tier 4:**<br>Vessel activity associated with operation of activities at offshore wind farm projects where full applications have not yet been submitted (Norfolk Boreas; East Anglia One North; East Anglia Two). | |
| Construction and Operation | Cumulative effect of increased collision risk from an increase in vessel activity across construction and operation of Hornsea Four alongside other operations requiring an increase in vessel activity. | Maximum design scenario for Hornsea Four plus the cumulative construction activities of the following projects:<br>**Tier 1:**<br>Vessels associated with decommissioning activities at Blyth Offshore Wind Farm<br>Vessels associated with offshore wind farm projects under construction and expected to be commissioned before the construction of Hornsea Four (Hornsea Project One, Hornsea Project Two, East Anglia One, Neart na Gaoithe, Moray East, Beatrice, Triton Knoll, Borssele II, THV Mermaid, Borkum Riffgrund II, Borkim Riffgrund West II, Deutche Bucht Pilot)<br>**Tier 2:**<br>Vessel activity associated with construction and operation of consented offshore wind farm projects not yet under construction but where construction predicted to overlap with Horsnea Four (Sofia; Dogger Bank Teeside A)<br>Vessels associated with offshore wind farm projects consented but not yet under construction but which are expected to be commissioned before the construction of Hornsea Four (Dogger Bank Creyke Bank A & B, East Anglia Three, Inch Cape, Seagreen Alpha and Bravo, Moray West)<br>**Tier 3:**<br>Vessel activity associated with construction and operation of activities at offshore wind farm projects that have been submitted but not yet determined (Hornsea Three; Norfolk Vanguard, Thanet Extension)<br>**Tier 4:** | Maximum potential for cumulative effects from the increased risk of collision from an increase in vessel activity is considered within the relevant management unit/area for each species. This spatial scale was chosen as a result of the high mobility of marine mammal receptors. |

| Project Phase | Potential Impact | Maximum Design Scenario | Justification |
|---|---|---|---|
| | | Vessel activity associated with construction and UXO clearance activities at offshore wind farm projects where full applications have not yet been submitted (Norfolk Boreas; East Anglia One North; East Anglia Two). | |

4.12.1.12 A description of the significance of cumulative effects upon marine mammals arising from each identified impact is given below. The cumulative effects assessment has been based on information available in ESs and it is noted that the project parameters quoted within ESs are often refined during the determination period and in the post-consent phase. The assessment presented here is therefore considered to be conservative, with the level of impacts in the as built projects expected to be reduced compared to those presented here.

### 4.12.2 Construction Phase

*Underwater noise during the construction of Hornsea Four cumulatively with other plans and projects*

4.12.2.1 The results of the Hornsea Four quantitative assessment have been combined with information from quantitative assessments presented in submitted assessments (ESs and PEIRs). Project specific values have been used wherever possible to account for variations in project design (pile types, hammer energies) and site-specific differences in species density. Where detailed quantitative information is not available, assumptions have been made as follows with respect to the predicted areas over which disturbance could occur, the duration and number of events and the number of porpoises disturbed:

- A disturbance range of 26 km from UXO detonation locations. This means that a total of 1,869 harbour porpoises and 510 grey seals are predicted to be disturbed per UXO detonation on average (using the Block O SCANS III harbour porpoise density estimate of 0.88 porpoises per $km^2$) and a total of 510 grey seals (using the average grey seal density calculated over the Northeast and Southeast England grey seal management area);
- Assuming a single UXO detonation per day for a total of 90 days prior to the construction period of each offshore wind farm project. This is considered to be a conservative overall average estimate taking into account the likely geographical variation in number of UXOs across the whole of the North Sea;
- A disturbance range of 10 km around seismic operations. This means that a total of 276 harbour porpoises and 75 grey seals are disturbed by each operation;
- During piling operations no additional disturbance is included as a result of vessel activity but during the non-piling parts of each offshore wind farm construction schedule, a small local disturbance effect of a maximum radius of 1 km is assumed as a result of non-piling construction noise (including vessels) (this equates to 3 porpoises and a single grey seal); and
- A total of two seismic surveys ongoing at any one time.

4.12.2.2 The approach of summing across concurrent activities is very conservative as it assumes that there is no spatial overlap between individual activities which is highly unrealistic, particularly considering the close proximity of many of the offshore wind farm projects to each other.

4.12.2.3 Underwater noise from non-piling activities during construction (vessel activity, seabed preparation, cable laying etc.) will be limited to a few tens of metres around each operation since any disturbance will be limited to the area directly around where the activity is taking place.

4.12.2.4 The greatest and most significant underwater noise is likely to be associated with the UXO clearance and pile driving phases of construction and therefore this element of the cumulative assessment considers the total potential disturbance of marine mammals during piling and UXO clearance for the proposed Hornsea Four project with piling at other offshore windfarm projects screened into the CEA, where there is the potential for these noisy construction activities to be going on at the same time as those at Hornsea Four (or immediately preceding or after).

4.12.2.5 The assessment has been undertaken based on the most realistic maximum design scenario of the offshore windfarms screened into the CEA. This most realistic, maximum design takes into account potential build scenarios making a number of assumptions in relation to project timings.

*Tier 1*

4.12.2.6 There are no offshore windfarm projects in Tier 1 with overlapping construction activities with those at Hornsea Four. The only potential for cumulative impact across offshore wind farm projects is from decommissioning activities at Blyth. However, these activities are likely to be localised, small scale and temporary and being ~150 km away from Hornsea Four, effects are unlikely to contribute significantly to any cumulative impact alongside Hornsea Four.

4.12.2.7 Due to the limited number of projects included in Tier 1, all marine mammals have been considered together. The cumulative impact of disturbance from underwater noise in Tier 1 projects for all marine mammals is predicted to be of local spatial extent, short-term duration, intermittent and reversible. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.8 Full discussion of the sensitivity of marine mammal species to disturbance from underwater noise is discussed in **Section 4.10.4**, which conclude that marine mammals have at worst, medium sensitivity to disturbance. Overall, the sensitivity of these receptors is therefore considered to be **medium**.

4.12.2.9 The maximum sensitivity of marine mammal receptors is **medium** and the magnitude has been assessed as **minor**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 1 projects is **minor** adverse, which is not significant in EIA terms.

*Tier 2*

*Harbour porpoise*

4.12.2.10 The only offshore windfarm projects in Tier 2 with the potential for overlapping construction activities with those at Hornsea Four are Sofia and Dogger Bank Teeside A. **Figure 4.6** displays the total number of porpoise potentially affected by disturbance from underwater noise across all Tier 2 plans and projects alongside Hornsea Four. In addition to the assumptions relating to UXO clearance and seismic survey detailed above, this is calculated based on the total number of piles to be installed at each project, assuming a conservative installation rate of between 1 and 2 monopiles per day, and assuming an average of 12 suitable piling days per month. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 1% of the total harbour porpoise population. The maximum level of disturbance is 2.7% which occurs in the event that Sofia and Hornsea Four are pile driving at the same time, in addition to ongoing seismic surveys. However, this overlap is limited to a maximum period of eight months.

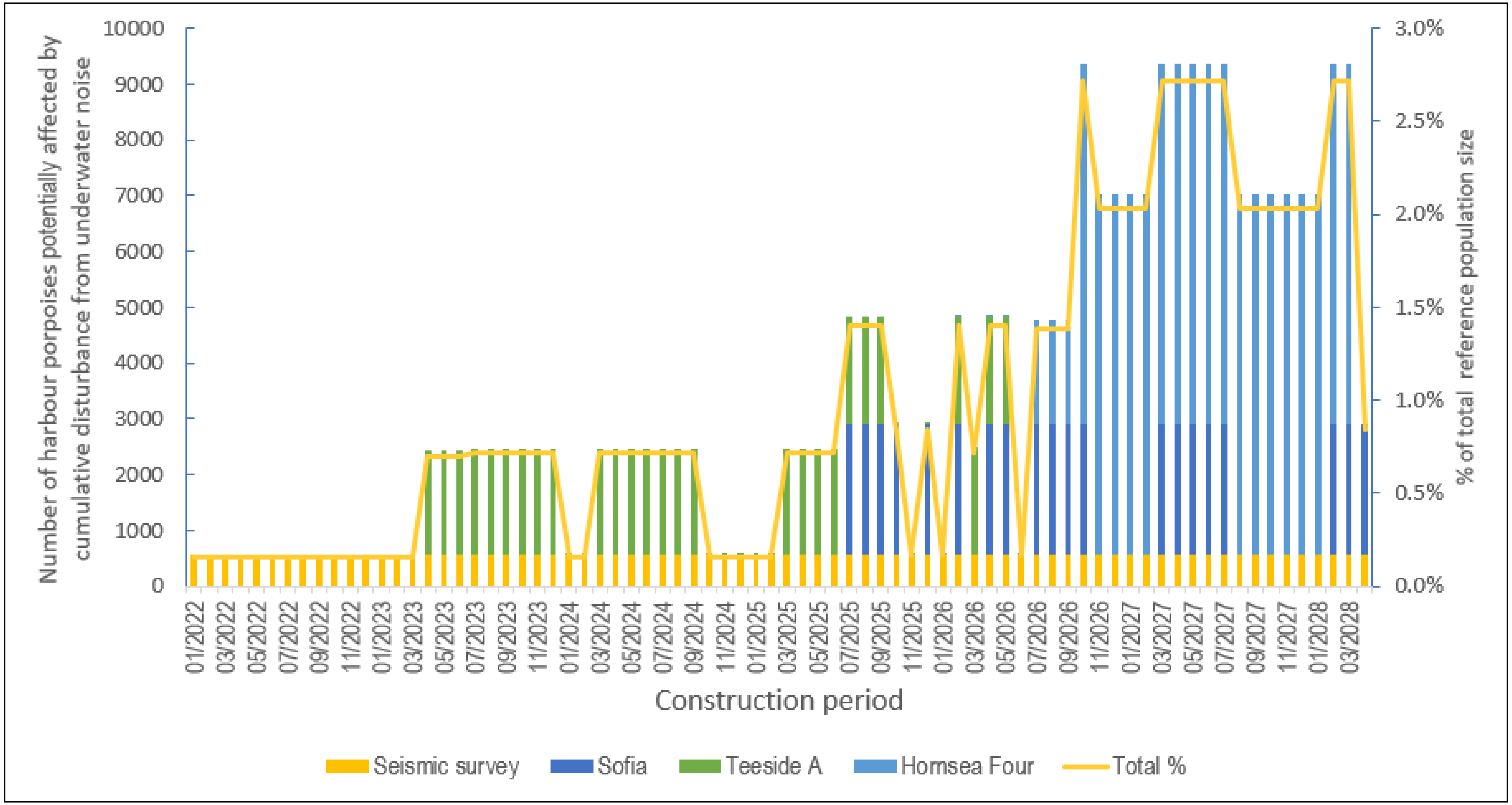


**Figure 4.6: Total cumulative harbour porpoise impact from underwater noise disturbance across all Tier 2 activities based in an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.11 The cumulative impact of disturbance from underwater noise in Tier 2 projects for harbour porpoises, is predicted to be of local spatial extent, medium-term duration, intermittent and reversible. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.12 As discussed in **paragraph 4.10.4** the sensitivity of harbour porpoise to disturbance from underwater noise is **medium**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 2 projects is **minor** adverse, which is not significant in EIA terms.

*Grey seals*

4.12.2.13 **Figure 4.7** displays the total number of grey seals potentially affected by disturbance from underwater noise across all Tier 2 plans and projects within the appropriate grey seal management areas alongside Hornsea Four. The total additional disturbance from other offshore wind farm projects (including associated UXO clearance) is minimal. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 0.76% of the total grey seal reference population. The maximum level of disturbance is 2.13% which occurs in the event that Sofia and Hornsea Four are pile driving at the same time as ongoing seismic surveys. However, this overlap is limited to a maximum period of eight months. Hornsea Four construction and ongoing seismic surveys within the management area at the same time results in disturbance to a total of 2.12% of the reference population. This is expected to be ongoing throughout the whole of the Hornsea Four pile driving period which will be for a maximum of 12 months.


**Figure 4.7: Total cumulative grey seal impact from underwater noise disturbance across all Tier 2 activities based in an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.14 The cumulative impact of disturbance from underwater noise in Tier 2 projects for grey seals, is predicted to be of local spatial extent, medium-term duration, intermittent and reversible affecting at most approximately 2% of the population but on average over the whole period affecting less than 1%. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.15 As discussed in **paragraph 4.10.4** the sensitivity of grey seals to disturbance from underwater noise is low. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 2 projects is **minor** adverse, which is not significant in EIA terms.

*Tier 3*

*Harbour porpoise*

4.12.2.16 In addition to the Tier 1 and Tier 2 projects detailed above, the offshore windfarm projects in Tier 3 with the potential for overlapping construction activities with those at Hornsea Four are Hornsea Three and Norfolk Vanguard. **Figure 4.8** displays the total number of porpoise potentially affected by disturbance from underwater noise across all Tier 1, Tier 2 and Tier 3 plans and projects alongside Hornsea Four. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 1.8% of the total harbour porpoise population. The maximum level of disturbance is 4.2% which occurs in the event that Sofia, Hornsea Three and Hornsea Four are pile driving at the same time in addition to ongoing seismic surveys. However, this overlap is limited to a maximum period of seven months.

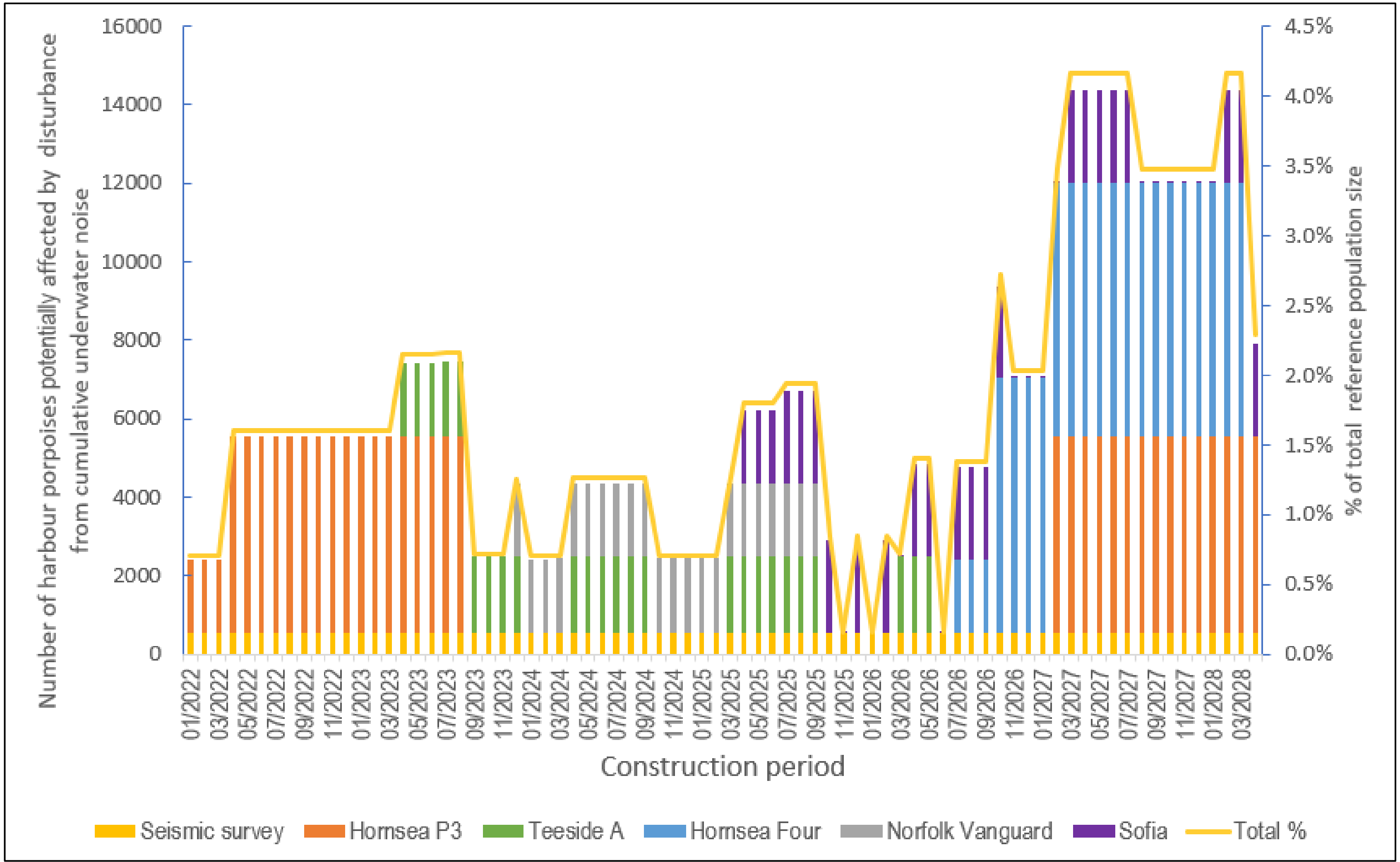


**Figure 4.8 Total cumulative harbour porpoise impact from underwater noise disturbance across all Tier 1, 2 and 3 activities based in an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.17 The cumulative impact of disturbance from underwater noise across Tier 1, Tier 2 and Tier 3 projects for harbour porpoises, is predicted to be of regional spatial extent, medium-term duration, intermittent and reversible, affecting at most approximately 4% of the population but on average over the whole period affecting less than 2%. This level of disturbance is not predicted to have a significant effect on the harbour porpoise population size or trajectory. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.18 As discussed in **paragraph 4.10.4** the sensitivity of harbour porpoise to disturbance from underwater noise is **medium**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 1, Tier 2 and Tier 3 projects is **minor** adverse, which is not significant in EIA terms.

*Grey seals*

4.12.2.19 **Figure 4.9** displays the total number of grey seals potentially affected by disturbance from underwater noise across all Tier 1, Tier 2 and Tier 3 plans and projects alongside Hornsea Four. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 0.9% of the total grey seal reference population. The maximum level of disturbance is 2.23% which occurs in the event that Sofia, Hornsea Three and Hornsea Four are pile driving at the same time, in addition to ongoing seismic surveys. However, this overlap is limited to a maximum period of seven months.

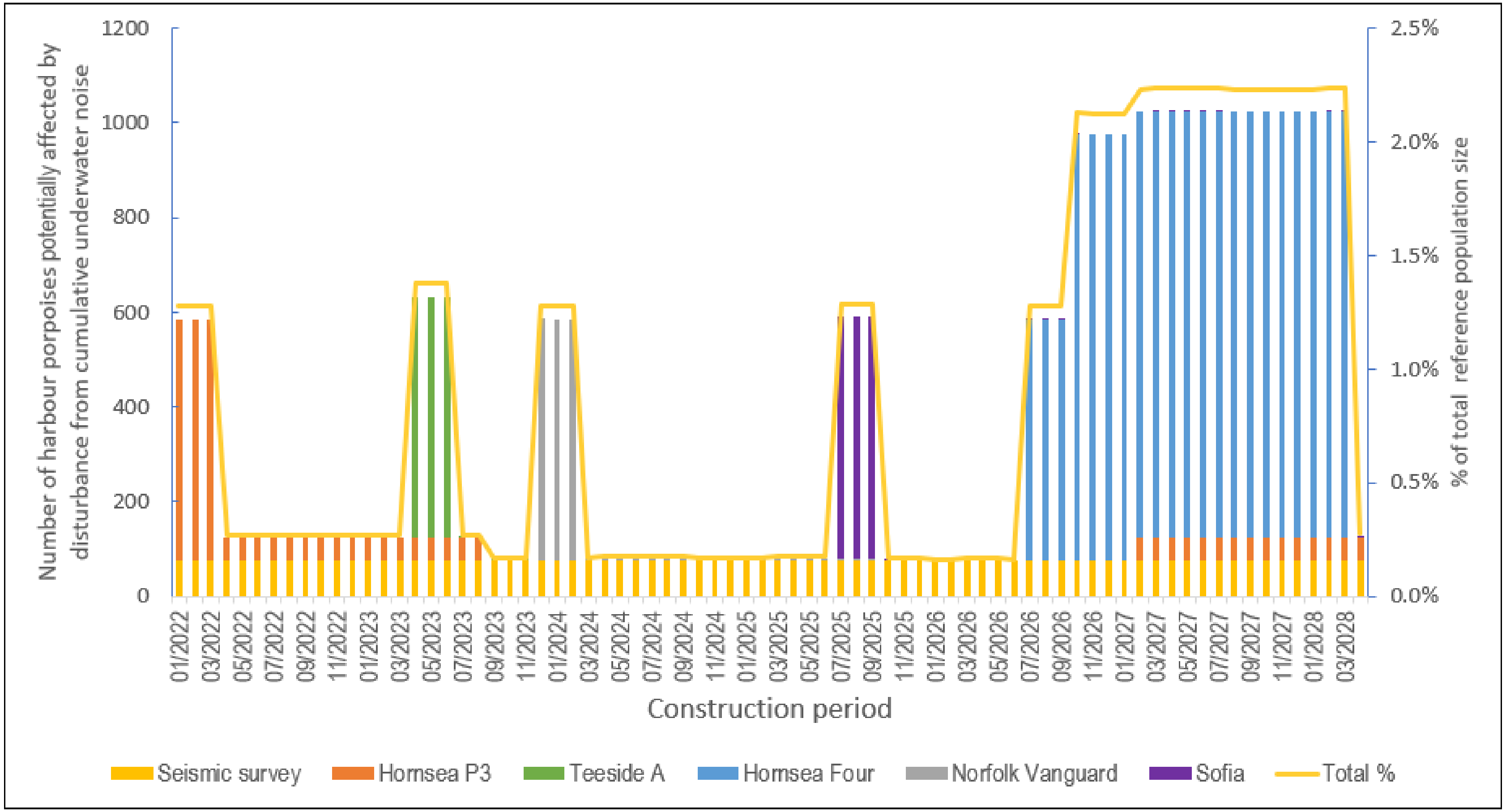


**Figure 4.9: Total cumulative grey seal impact from underwater noise disturbance across all Tier 1, 2 and 3 activities based on an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.20 The cumulative impact of disturbance from underwater noise across Tier 1, Tier 2 and Tier 3 projects for grey seals, is predicted to be of regional spatial extent, medium-term duration, intermittent and reversible, affecting at most approximately 2% of the population, but on average over the whole period affecting less than 1%. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.21 As discussed in **paragraph 4.10.4** the sensitivity of grey seals to disturbance from underwater noise is **low**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 1, Tier 2 and Tier 3 projects is **minor** adverse, which is not significant in EIA terms.

*Tier 4*

*Harbour porpoise*

4.12.2.22 In addition to the Tier 1, 2 and 3 projects detailed above, the offshore wind farm projects in Tier 4 with the potential for overlapping construction activities with those at Hornsea Four are Norfolk Boreas, East Anglia One North and East Anglia Two. **Figure 4.10** displays the total number of porpoise potentially affected by disturbance from underwater noise across all Tier 1, 2, 3 and 4 plans and projects alongside Hornsea Four. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 2.1% of the total harbour porpoise population. The maximum level of disturbance is 5.6% which occurs in the event that Sofia, Hornsea Three, Norfolk Boreas, East Anglia One North, East Anglia Two and Hornsea Four are pile driving at the same time as well as ongoing seismic activity. However, this overlap is limited to a maximum period of five months.

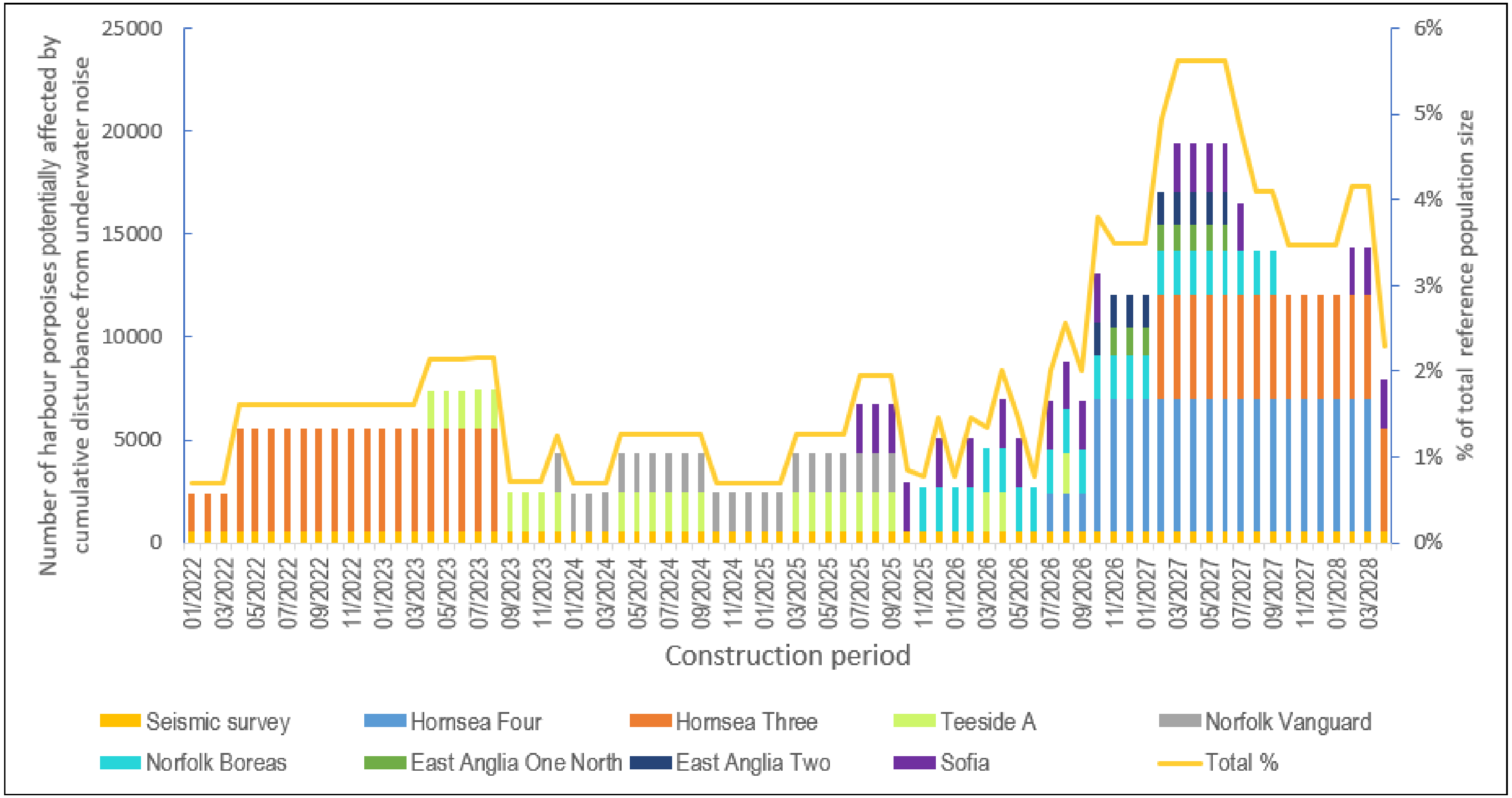


**Figure 4.10: Total cumulative harbour porpoise impact from underwater noise disturbance across all Tier 1, 2, 3 and 4 activities based on an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.23 The cumulative impact of disturbance from underwater noise in Tier 1, 2, 3 and 4 projects for harbour porpoises, is predicted to be of regional spatial extent, medium-term duration, intermittent and reversible, affecting at most approximately 5-6% of the total North Sea harbour porpoise population, but on average over the period affecting around 2%. This level of disturbance is not predicted to have a significant effect on the harbour porpoise population size or trajectory. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.24 As discussed in **paragraph 4.10.4** the sensitivity of harbour porpoise to disturbance from underwater noise is **medium**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 1, 2, 3 and 4 projects is **minor** adverse, which is not significant in EIA terms.

*Grey seals*

4.12.2.25 **Figure 4.11** displays the total number of grey seals potentially affected by disturbance from underwater noise across all Tier 1, 2, 3 and 4 plans and projects alongside Hornsea Four. Across the total period considered (January 2022 to April 2028), the average monthly magnitude of disturbance is equivalent to 0.8% of the total grey seal population. The maximum level of disturbance is 3.5% which occurs in the event that pile driving is occurring at Sofia, Dogger Bank Teeside A and Norfolk Boreas, at the same time that UXO clearance is taking place at Hornsea Four, East Anglia One North and East Anglia Two, alongside ongoing seismic surveys. However, this maximal overlap is limited to a maximum period of three months.

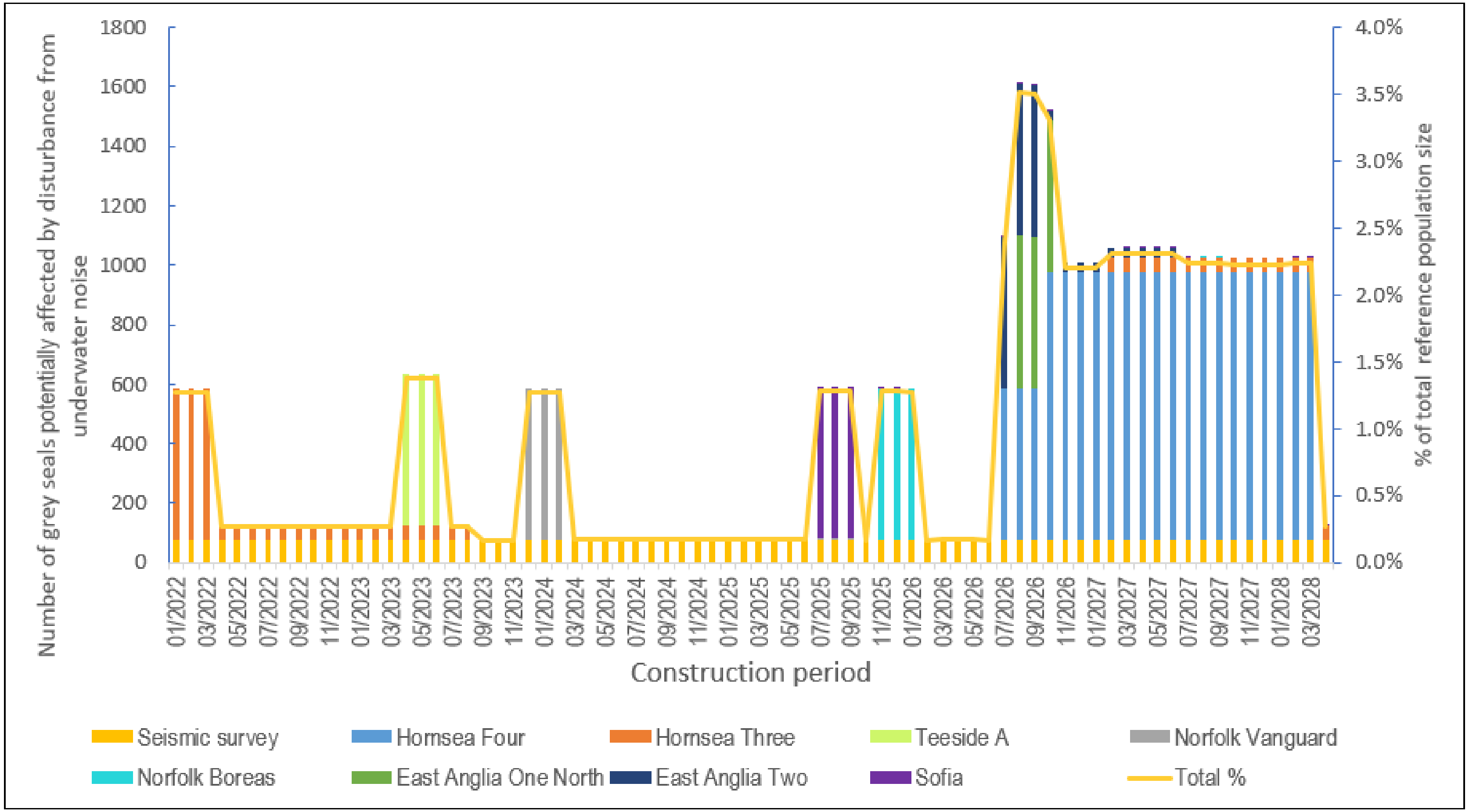


**Figure 4.11: Total cumulative grey seal impact from underwater noise disturbance across all Tier 1, 2, 3 and 4 activities based on an indicative realistic maximum design build scenario (UXO clearance prior to pile driving and disturbance from non-piling construction noise is incorporated within each windfarm project).**

4.12.2.26 The cumulative impact of disturbance from underwater noise across Tier 1, 2, 3 and 4 projects for grey seals is predicted to be of regional spatial extent, medium-term duration, intermittent and reversible, affecting at most 3.5% of the total grey seal population but on average over the period affecting approximately 1%. This level of disturbance is not predicted to have a significant effect on the trajectory or size of the grey seal population. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.27 As discussed in **paragraph 4.10.4** the sensitivity of grey seals to disturbance from underwater noise is **low**. Therefore, the significance of effect from disturbance from underwater noise from the installation of Hornsea Four cumulatively with all Tier 1, 2, 3 and 4 projects is **minor** adverse, which is not significant in EIA terms.

*Tier 5*

4.12.2.28 No quantitative assessment has been carried out for Tier 5 projects due to the lack of information on the timing and nature of these projects. Given the likely construction timeline of projects that have not yet submitted any information in the form of Scoping reports or PEIR, it is considered highly unlikely that construction activities will overlap with those of Hornsea Four, therefore there is no additional cumulative impact for any marine mammal species.

*Vessel collision during construction of Hornsea Four cumulatively with other plans and projects*

4.12.2.29 It is extremely difficult to reliably quantify the increased collision risk to marine mammals resulting from increased vessel activity on a cumulative basis given the large degree of temporal and spatial variation in vessel movements between projects and regions, coupled with the spatial and temporal variation in marine mammal movements across the region. This cumulative assessment considers the increased potential for collision with marine mammals, due to the potential increase in vessel movements from the construction of the Hornsea Four offshore windfarm with other planned or existing projects, plans and activities.

4.12.2.30 The activities that were considered are:

- Offshore windfarms where construction phases overlap with the construction and operational and maintenance phases of Hornsea Four; and
- Cable and pipeline projects that have not yet commenced construction but where construction is expected to overlap with vessel activities at Hornsea Four.

4.12.2.31 Vessel routes to and from offshore windfarms and other projects will use existing vessel routes where marine mammals will be accustomed to, and potentially habituated to regular vessel movements and therefore the additional risk is confined mainly to construction sites. Vessel movements within construction areas are likely to be limited and relatively slow. In addition, most projects are likely to adopt vessel management plans in order to minimise any potential effects on marine mammals.

4.12.2.32 Table 4.38 presents the quantitative information that is available for all projects screened into the CEA for vessel collision, covering the construction phase vessel movements expected for each project.

4.12.2.33 The cumulative impact of increased collision risk is predicted to be of regional spatial extent, medium-term duration, intermittent and although if impacted the effect is irreversible for individuals, the overall increased risk is considered to be low. The low level of predicted additional mortality due to collision with vessels is not predicted to have a significant effect on the trajectory or size of any marine mammal population. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.2.34 As discussed in paragraph 4.11.1.57 *et seq.*, the sensitivity of all marine mammals to increased collision risk from vessels is considered to be medium. Therefore, the significance of the cumulative effect from increased vessel activity is **minor** adverse, which is not significant in EIA terms.

**Table 4.38: CEA projects – predicted additional vessel activity.**

| Tier | Project | Construction vessel MDS – maximum number of vessel movements |
|---|---|---|
| | Hornsea Four | 1,830 over 4 years |
| 2 | Sofia | 5,810 in total over 6 years |
| 2 | Dogger Bank Teesside A | 5,810 in total over 6 years |
| 3 | Hornsea Three | Up to 10,774 in total (spread over a total construction period of 8 years in two phases) |
| 3 | Norfolk Vanguard | 1,180 in total single phase or 2 x 590 in two phases |
| 4 | Norfolk Boreas | 1,180 in total over 2 years |
| 4 | East Anglia One North | 3,335 total trips over 27 month construction period |
| 4 | East Anglia Two | 3,672 total trips (average 1,632 per year/136 per month) |

### 4.12.3 Operation and Maintenance Phase

*Disturbance from vessel noise during the operation of Hornsea Four cumulatively with other plans and projects*

4.12.3.1 It is extremely difficult to reliably quantify the level of increased noise related disturbance to marine mammals resulting from increased vessel activity on a cumulative basis given the large degree of temporal and spatial variation in vessel movements between projects and regions, coupled with the spatial and temporal variation in marine mammal movements across the region.

4.12.3.2 As noted above, vessel routes to and from offshore windfarms and other projects will use existing vessel routes where marine mammals will be accustomed to regular vessel movements and therefore the underwater noise from vessels will already be an existing feature of the ambient noise landscape. Vessel activity within array areas are likely to be limited and relatively slow.

4.12.3.3 Increases in underwater noise from vessels during the operational phases of projects are likely to be small in relation to current and ongoing levels of shipping.

4.12.3.4 The cumulative impact of increased underwater noise from vessels is predicted to be of local spatial extent, long term duration, intermittent and reversible. The low level of predicted additional disturbance is not predicted to have a significant effect on the trajectory or size of any marine mammal population. It is therefore predicted that the impact will be of **minor** magnitude.

4.12.3.5 As discussed in **Section 4.11.2** *et seq.*, the sensitivity of all marine mammals to underwater from vessels is considered to be **medium**. Therefore, the significance of the cumulative effect from underwater noise from increased vessel activity is **minor** adverse, which is not significant in EIA terms.

*Vessel collision during the operation of Hornsea Four cumulatively with other plans and projects*

4.12.3.6 It is extremely difficult to reliably quantify the level of increased collision risk to marine mammals resulting from increased vessel activity on a cumulative basis given the large degree of temporal and spatial variation in vessel movements between projects and regions, coupled with the spatial and temporal variation in marine mammal movements across the region. This part of cumulative assessment considers the increased potential for collision with marine mammals, due to the potential increase in vessel movements from the operation of Hornsea Four with other planned or existing projects, plans and activities.

4.12.3.7 Vessel routes to and from offshore windfarm and other projects will use existing vessel routes where marine mammals will be accustomed to regular vessel movements and therefore the additional risk is confined mainly to the offshore wind farm sites themselves. Vessel movements within array areas area likely to be limited and relatively slow. In addition, most projects are likely to adopt vessel management plans to ensure the risk of collision to marine mammals is minimised. Marine mammals in the area are also likely to be habituated to the presence of vessels.

4.12.3.8 Increases in vessel movements during the operational phases of projects are likely to be small in relation to current and ongoing levels of shipping.

4.12.3.9 The cumulative impact of increased collision risk is predicted to be of regional spatial extent, long term duration, intermittent and although if impacted the effect is irreversible for individuals, the overall increased risk is considered to be low. The low level of predicted additional mortality due to collision with vessels is not predicted to have a significant effect on the trajectory or size of any marine mammal population. It is therefore predicted that the impact will be of **low** magnitude.

4.12.3.10 As discussed in **paragraph 4.11.1.57** *et seq.*, the sensitivity of all marine mammals to increased collision risk from vessels is considered to be **medium**. Therefore, the significance of the cumulative effect from increased vessel activity is **minor** adverse, which is not significant in EIA terms.

## 4.13 Transboundary effects

4.13.1.1 Transboundary effects are defined as those effects upon the receiving environment of other European Economic Area (EEA) states, whether occurring from Hornsea Four alone, or cumulatively with other projects in the wider area. A transboundary screening exercise was undertaken at Scoping (Annex K of the Scoping Report), which identified that there was the potential for transboundary effects to occur in relation to marine mammals. The potential transboundary impacts screened into the assessment for marine mammals were:

- Underwater noise generated during construction and decommissioning, particularly piling during the installation of foundations; and
- Disturbance to prey (fish) species from loss of fish spawning and nursery habitat and suspended sediments and deposition.

4.13.1.2 Behavioural disturbance resulting from underwater noise during construction could occur over large ranges (tens of kilometres) and therefore there is the potential for transboundary effects to occur where subsea noise arising from Hornsea Four could extend into waters of other EEA states. These impacts were predicted to be short term and intermittent, with recovery of marine mammal populations to affected areas following completion of all piling activities. Overall, the sensitivity of marine mammal receptors to behavioural disturbance was assessed as **medium** to **low** and the magnitude predicted to be **negligible** to **minor** adverse. The effect was therefore considered to be a maximum of **minor** significance, which is not considered significant in EIA terms.

4.13.1.3 Effects of reduction in prey availability are predicted to be limited in extent to a number of kilometres of Hornsea Four and are therefore not predicted to extend into the waters of other EEA states. **Volume 2, Chapter 3: Fish and Shellfish Ecology** concluded no significant impacts on all fish species. Therefore, the impact of a reduction in prey ability will not lead to a significant effect.

## 4.14 Inter-related effects

4.14.1.1 Inter-related effects consider impacts from the construction, operation or decommissioning of Hornsea Four on the same receptor (or group). The potential inter-related effects that could arise in relation to marine mammals are presented in **Table 4.39**. Such inter-related effects include both:

- Project lifetime effects: i.e. those arising throughout more than one phase of the project (construction, operation, and decommissioning) to interact to potentially create a more significant effect on a receptor than if just one phase were assessed in isolation; and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor (or group). Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

4.14.1.2 A description of the process to identify and assess these effects is presented in **Section 5.8** of **Volume 1, Chapter 5: Environmental Impact Assessment Methodology**.

**Table 4.39: Inter-related effects assessment for marine mammals.**

| Project phase(s) | Nature of inter-related effect | Assessment alone | Inter-related effects assessment |
|---|---|---|---|
| *Project-lifetime effects* | | | |
| Construction and decommissioning | Disturbance from underwater noise | Disturbance from piling in the construction phase was assessed as minor and similar (or lesser) effects are expected for decommissioning. | Disturbance to marine mammals will be mainly caused by underwater noise from piling in the construction phase and removal of structures in the decommissioning phase. The construction and decommissioning phases are significantly temporally separate such that there will be no interaction between the two. Disturbance from underwater noise was assessed as not significant in EIA terms. Therefore, across the project lifetime, the effects on marine mammal receptors are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase. |
| Construction, operation and, decommissioning | Collisions and disturbance from vessels | Both collisions and disturbance from vessels were assessed as minor significance across | The potential for disturbance and/or collision effects will arise at all stages of the project, resulting in a potential project lifetime effect. However, it is not predicted that the significance of any potential effects will |

| Project phase(s) | Nature of inter-related effect | Assessment alone | Inter-related effects assessment |
|---|---|---|---|
| | | all three project phases. | increase due to the interaction of this impact across all project stages, rather be maintained at the same level throughout the project. With the implementation of a VMP, impacts from vessel activity is assessed as minor and therefore not significant across all three phases. Therefore, across the project lifetime, the effects on marine mammals are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase. |
| *Receptor-led effects* | | | |
| Inter-related effect from the combination of disturbance from underwater noise, the presence of vessels and loss of prey resources on marine mammals. | | The greatest potential for spatial and temporal interactions is likely to occur with underwater construction noise impacts (i.e. during the construction phase). The individual impacts were assigned significance of negligible to minor. It is noted that some of these interactions are mutually exclusive (i.e. disturbance/displacement resulting from underwater noise will mean reduced potential for vessel interactions). It is therefore not anticipated that any inter-related effects will be produced that are of greater significance than the assessments presented for each individual phase. | |

## 4.15 Conclusion and summary

4.15.1.1 This chapter has investigated the potential effects on marine mammal receptors arising from Hornsea Four. The range of potential impacts and associated effects considered has been informed by the Scoping Opinion received on 26 November 2018 and agreed through Evidence Plan Technical Meetings, as well as reference to existing policy and guidance. The impacts considered include those brought about directly (e.g. underwater noise from construction activities), as well as indirectly (e.g. a reduction in prey availability).

4.15.1.2 Characterisation of the baseline environment through both survey data from the former Hornsea Zone and within the Hornsea Four study area and a desk-based literature review found that the key marine mammal receptors were harbour porpoise, minke whales, white-beaked dolphins, harbour seals and grey seals.

4.15.1.3 Table 4.40 presents a summary of the impacts assessed within this PEIR chapter, any commitments made and mitigation required and the residual effects. The project-alone impact assessment has not identified any significant impacts on any marine mammal receptors.

4.15.1.4 The assessment of cumulative impacts from Hornsea Four and other developments and activities, including offshore wind farms and aggregate extraction, concluded that the effects of any cumulative impacts would generally be of **minor** significance, and not significant in EIA terms.

4.15.1.5 The screening of transboundary impacts identified that there was potential for transboundary effects for marine mammals from Hornsea Four upon the interests of other European Economic Area (EEA) States. However, following consideration of the relevant impact assessments, these impacts were not predicted to have significant effects on marine mammal populations of other EEA States.

**Table 4.40: Summary of potential impacts assessed for marine mammals. HP= harbour porpoise, MW = minke whale, WBD = white-beaked dolphin, HS = harbour seal, GS = grey seal.**

| Impact and Phase | Receptor | Magnitude | Sensitivity | Impact significance | Mitigation | Residual impact |
|---|---|---|---|---|---|---|
| *Construction* | | | | | | |
| PTS from piling noise | All | Negligible | Not Significant | | | |
| Disturbance from piling noise | HP | Minor | Medium | Minor | Co110 | Minor |
| | MW, WBD, HS | Negligible | Not Significant | | | |
| | GS | Minor | Low | Minor | Co110 | Minor |
| Vessel collision risk | All | Minor | Medium | Minor | Co108 | Minor |
| Disturbance from vessels | All | Minor | Low | Minor | Co108 | Minor |
| Non-piling noise | All | Negligible | Not Significant | | | |
| Reduction in prey availability | All | Negligible | Not Significant | | | |
| Reduction in foraging ability | All | Negligible | Not Significant | | | |
| PTS from UXO clearance | All | Negligible | Not Significant | | | |
| Disturbance from UXO clearance | All | Negligible | Not Significant | | | |
| *Operation* | | | | | | |
| Operational noise | All | Minor | Low | Minor | None | Minor |
| Vessel collision risk | All | Minor | Medium | Minor | Co108 | Minor |
| Disturbance from vessels | All | Minor | Low | Minor | Co108 | Minor |
| Reduction in prey availability | All | Negligible | Not Significant | | | |
| Reduction in foraging ability | All | Negligible | Not Significant | | | |
| *Decommissioning* | | | | | | |
| PTS from underwater noise | HP | Minor | Medium | Minor | Co111 | Minor |
| | MW, WBD, HS, GS | Negligible | Not Significant | | | |
| Disturbance from underwater noise | HP | Minor | Medium | Minor | Co111 | Minor |
| | MW, WBD, HS | Negligible | Not Significant | | | |
| | GS | Minor | Low | Minor | Co111 | Minor |
| Vessel collision risk | All | Minor | Medium | Minor | Co108 | Minor |
| Disturbance from vessels | All | Minor | Low | Minor | Co108 | Minor |

| Impact and Phase | Receptor | Magnitude | Sensitivity | Impact significance | Mitigation | Residual impact |
|---|---|---|---|---|---|---|
| Reduction in prey availability | All | Negligible | Not Significant | | | |
| Reduction in foraging ability | All | Negligible | Not Significant | | | |

## 4.16 References

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## 4.17 Appendix A - Range dependent characteristics of impulsive sounds

4.17.1.1 Exposure to loud, brief, transient sounds (impulsive sounds, such as explosions, airgun shots or pile strikes) is more damaging to the mammalian ear as it increases the hearing threshold faster than exposure to non-impulsive sound (such as from drilling and shipping), i.e. less sound energy is needed to induce TTS or PTS. Therefore, Southall *et al.* (2019) presents two different sets of noise thresholds, one for impulsive and one for non-impulsive sound.

4.17.1.2 Southall *et al.* (2019) acknowledges that, as a result of propagation effects, the signal of certain sound sources (e.g., pile driving) loses its impulsive characteristics and could potentially be characterised as a non-impulsive beyond a certain distance. The changes in noise characteristics with distance generally result in exposures becoming less physiologically damaging with increasing distance as sharp transient peaks become less prominent (Southall *et al.* 2019). The Southall *et al.* (2019) updated criteria proposed that, while keeping the same source categories, the exposure criteria for impulsive and non-impulsive sound should be applied based on the signal features likely to be perceived by the animal rather than those emitted by the source. Methods to estimate the distance at which the transition from impulsive to non-impulsive noise are currently being developed (Southall *et al.* 2019).

4.17.1.3 In the draft version of the National Marine Fisheries Service (2018) guidance (NOAA guidance) that was released in 2015 for public consultation, four criteria were proposed to determine whether a signal is impulsive or non-impulsive in nature. These criteria were based on signal duration[8], rise time[9], crest factor[10] and peak pressure[11] divided by signal duration. The criteria were removed from the final 2016 guidance and its 2018 update. Nonetheless, Hastie *et al.* (2019) used these criteria to estimate the transition from impulsive to non-impulsive characteristics of pile driving noise during the installation of offshore wind turbine foundations at The Wash and in the Moray Firth based on sound recorded at increasing distances from the piling site. Southall *et al.* (2019) state that mammalian hearing is most readily damaged by transient sounds with rapid rise-time, high peak pressures, and sustained duration relative to rise-time. Therefore, of the four criteria used by Hastie *et al.* (2019), the rise-time and peak pressure may be the most appropriate indicators to determine the impulsive/non-impulsive transition. Signal duration alone may not be sufficient as it does not describe the signal's impulsiveness. Peak pressure/signal duration was used by Hastie *et al.*

[8] Time interval between the arrival of 5% and 95% of total energy in the signal.
[9] Measured time between the onset (defined as the 5$^{th}$ percentile of the cumulative pulse energy) and the peak pressure in the signal.
[10] The decibel difference between the peak sound pressure level (i.e. the peak pressure expressed in units of dB re 1 μPa) of the pulse and the root-mean-square sound pressure level calculated over the signal duration.
[11] The greatest absolute instantaneous sound pressure within a specified time interval.

(2019) as a proxy for rise-time, therefore, rise-time should be the preferred criteria where the information is available.

4.17.1.4 Based on the rise-time criterion (rise time <25 ms defines a signal as impulsive), Hastie *et al.* (2019) showed that the noise signal experienced a high degree of change in its impulsive characteristics within three to nine km from the source (Table A 1). For pile driving at the Moray Firth (1.8 m diameter pin-piles in 42 m water depth in 2006), the probability of the piling noise being impulsive reduced from 70% at ~0.7 km down to 1% at ~3.1 km (Figure A 1). For pile driving at The Wash (5.2 m diameter monopiles in water depths of 8-20 m in 2006 and 2012), this probability reduced from 70% at ~1.4 km down to 1% at ~8.6 km.

**Table A 1: Relationship between probability of a signal being defined as "impulsive" and range from the pile site, using the criteria of rise time being less than 25 ms. Values obtained from the supplementary data from Hastie *et al.* (2019) and as shown in Figure A 1.**

| Probability | Range to Pile Site (km) | | | | | |
|---|---|---|---|---|---|---|
| | Moray Firth | | | The Wash | | |
| | Mean | 95% CI | | Mean | 95% CI | |
| 0.9 | | | | | | 1.7 |
| 0.8 | 0.6 | | 0.8 | | | 2.3 |
| 0.7 | 0.9 | 0.7 | 1.0 | 1.4 | | 2.8 |
| 0.6 | 1.0 | 0.9 | 1.1 | 2.0 | | 3.2 |
| 0.5 | 1.2 | 1.1 | 1.3 | 2.5 | | 3.6 |
| 0.4 | 1.4 | 1.3 | 1.5 | 3.1 | | 4.1 |
| 0.3 | 1.6 | 1.5 | 1.7 | 3.7 | 1.5 | 5.0 |
| 0.2 | 1.8 | 1.7 | 1.9 | 4.4 | 3.2 | 6.9 |
| 0.1 | 2.1 | 2.0 | 2.3 | 5.4 | 4.4 | |
| 0.09 | 2.2 | 2.0 | 2.4 | 5.6 | 4.5 | |
| 0.08 | 2.2 | 2.1 | 2.4 | 5.8 | 4.6 | |
| 0.07 | 2.3 | 2.1 | 2.5 | 6.0 | 4.8 | |
| 0.06 | 2.4 | 2.2 | 2.6 | 6.2 | 4.9 | |
| 0.05 | 2.4 | 2.2 | 2.7 | 6.4 | 5.1 | |
| 0.04 | 2.5 | 2.3 | 2.8 | 6.7 | 5.3 | |
| 0.03 | 2.7 | 2.4 | 2.9 | 7.1 | 5.5 | |
| 0.02 | 2.8 | 2.6 | 3.2 | 7.7 | 5.9 | |
| 0.01 | 3.1 | 2.8 | 3.5 | 8.6 | 6.4 | |
| 0.005 | 3.4 | 3.1 | 3.8 | 9.5 | 7.0 | |

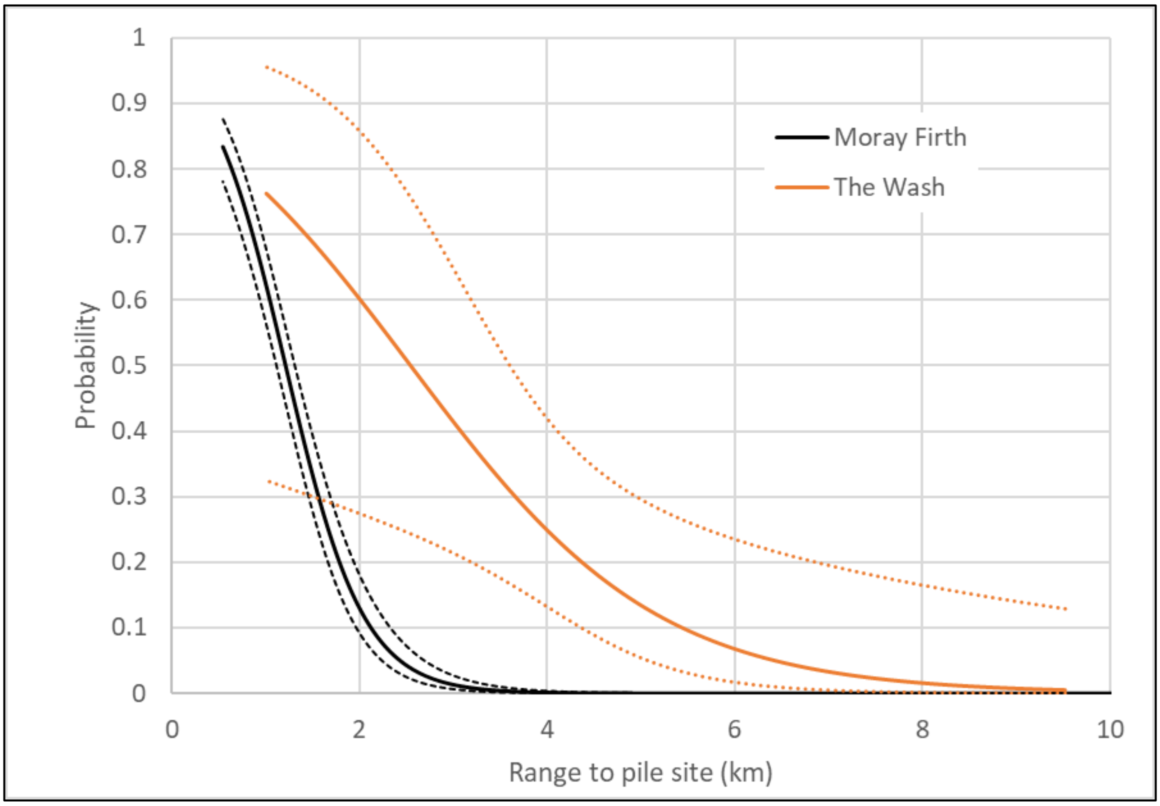


**Figure A 1: Modelled functions describing the probability of a signal being defined as "impulsive" based on the rise time being less than 25 ms. The lines represent the modelled fits (solid lines) and their 95% confidence intervals (dashed lines) for Moray Firth (black) and The Wash (orange). Figure adapted from Hastie *et al.* (2019).**

4.17.1.5 Predicted PTS impact ranges based on the impulsive noise thresholds will therefore overestimate the risk of PTS in cases and at ranges where the likelihood increases that an animal is exposed to non-impulsive sound. The data presented in Hastie *et al*. (2019) suggests that there is not a specific distance at which sounds lose their impulsiveness and therefore it is not possible to define a 'transition point' at which sounds switch from impulsive to non-impulsive. It is more likely that there is a 'transition zone' over which the probability of a sound being considered impulsive reduces. Beyond this zone, the probability of a sound being considered impulsive should be zero. Any animal present beyond this transition zone when piling starts will only be exposed to non-impulsive noise. For these ranges, non-impulsive thresholds should be applied. An animal present within the transition zone may be exposed to both impulsive and non-impulsive sound while moving through the transition zone during a sequence of pulses. How to evaluate the risk of PTS within the transition zone requires further consideration. One approach would be to define a level of acceptable probability beyond which all sounds are considered non-impulsive (e.g. 95% probability that sounds are non-impulsive). Whilst this approach may be acceptable for single exposures to sounds, exposure to multiple pulses is more complex and the cumulative probability of exposure to pulses must be considered. It is important to consider each of the noise threshold criteria (SPLpeak and SELcum) of the dual-criterion separately. This is explored further below.

4.17.1.6 Hastie *et al*. (2019) state that the relationship between noise characteristics and the change from impulsive to non-impulsive and the distance to the sound source is likely to depend on both static (e.g. seabed characteristics, water depth) and dynamic (e.g. sea state, tidal height) environmental parameters as well as source characteristics (e.g. hammer energy), and that further studies are needed to quantify this relationship. With reference to water depth and substrate type, the Hornsea Four site is more similar to the Moray Firth site than to The Wash. It could therefore be assumed that the range within which the transition zone can be expected at Hornsea Four is closer to that found at the Moray Firth than that found at The Wash. Currently, the best available data to estimate the transition zone range for Hornsea Four would be the sound recordings obtained during pile driving at Hornsea One, which could be analysed in a similar way to Hastie *et al*. (2019). In the absence of this analysis, all further discussions here are based on the Moray Firth data, with the assumption that these are most representative of the Hornsea Four area.

**Instantaneous PTS ($SPL_{peak}$)**

4.17.1.7 It only takes one single impulsive sound above the SPLpeak PTS threshold to induce instantaneous PTS. However, an animal swimming through the transition zone may be exposed to a series of pile strikes, each with an associated probability of being impulsive (single strike probability), and with this probability decreasing as the animal moves away from the source. Although this probability decreases on a per strike basis, the likelihood that the animal is exposed to at least one impulsive strike increases with each pile strike (multiple strike probability or cumulative probability) (Figure A 2). While the multiple strike probability shown in Figure A 2 is based on the animal being stationary for simplicity, this probability will likely be less for a moving animal and will depend on the animal speed and the strike rate of the piling. With a speed of 1.5 m/s and a strike rate of 30 strikes per minute, the animal moves 3 m between each strike, i.e. moving 30 m during 10 strikes. The multiple strike probability will, in this case, only be slightly below that of a stationary animal. For 100 strikes, at strike rate of 30 strikes per minute, the animal moves 300 m, and the multiple strike probability will be between that of a stationary animal at the starting position and that of a stationary animal at the starting position + 300 m. Figure A 2 illustrates that even at a distance at which the probability of a strike sound being impulsive is reduced to 1% (for the Moray Firth: 3.1 km), the likelihood that an animal is exposed to an impulsive sound during the exposure of multiple pile strikes with a sound level above the PTS threshold, is several times higher. The multiple strike probability can be estimated based on swim speed and strike rate, which may be a useful tool in cases where the PTS impact range for impulsive sound is longer than the ranges at which the single strike probability near 0. For Hornsea Four however, the instantaneous PTS ranges are within the transition ranges discussed here, and therefore these calculations are not needed for this particular project.

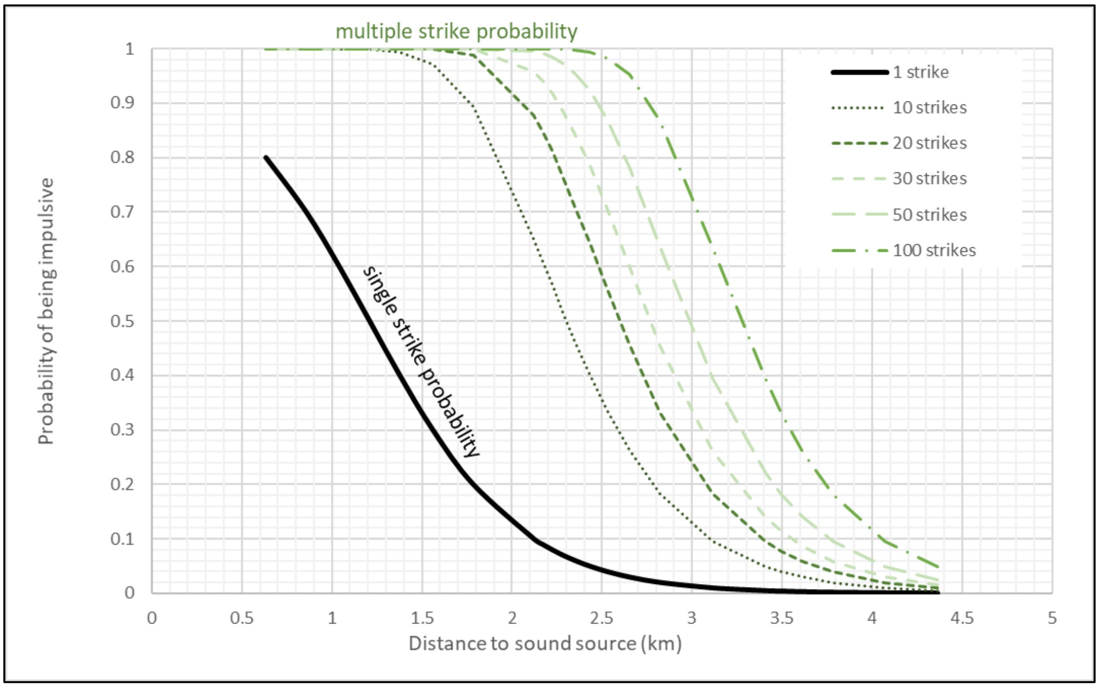


**Figure A 2: Single strike (black) and multiple strike (green) probability of an animal being exposed to an "impulsive" strike based on the rise time (see Figure 1, Moray Firth). The figure shows the probability that at least one out of a series of strikes is impulsive (multiple strike probability - given are different examples from 10 to 100 strikes) based on the probability of each individual strike to be impulsive (single strike probability). This example is for stationary animals.**

**PTS from cumulative exposure ($SEL_{cum}$)**

4.17.1.8 For cumulative SEL PTS impact ranges, all strikes within a piling sequence are considered in the calculations. As the animal moves away from the pile site, the energy of each strike the animal is exposed to is summed to calculate the SELcum. With each doubling of the sound energy, the SELcum increases by 3 dB (see Figure A 3). This means that for a 3 dB increase in SELcum, it needs twice as much energy as for the preceding 3 dB rise. This logarithmic relationship between energy and SEL leads to a fast increase in SELcum during the first strikes of a piling sequence, which flattens with increasing number of strikes. This in turn explains why the energy and characteristics of the initial strikes an animal is exposed to are highly influential on the risk of an animal experiencing PTS. The SELcum PTS impact range is a measure of the minimum distance (safe distance) at which an animal can start at, at the onset of piling, while the energy it is exposed to adds up to an SELcum value below the PTS threshold. If the resulting safe distance is within or beyond the transition zone, the impulsive PTS impact ranges are likely to be overestimated. This is because each sound that is non-impulsive leads to a smaller hearing threshold shift than would be the case for impulsive sound. Where an animal is exposed to both impulsive and non-impulsive sounds neither threshold is particularly appropriate, and a different approach is required.

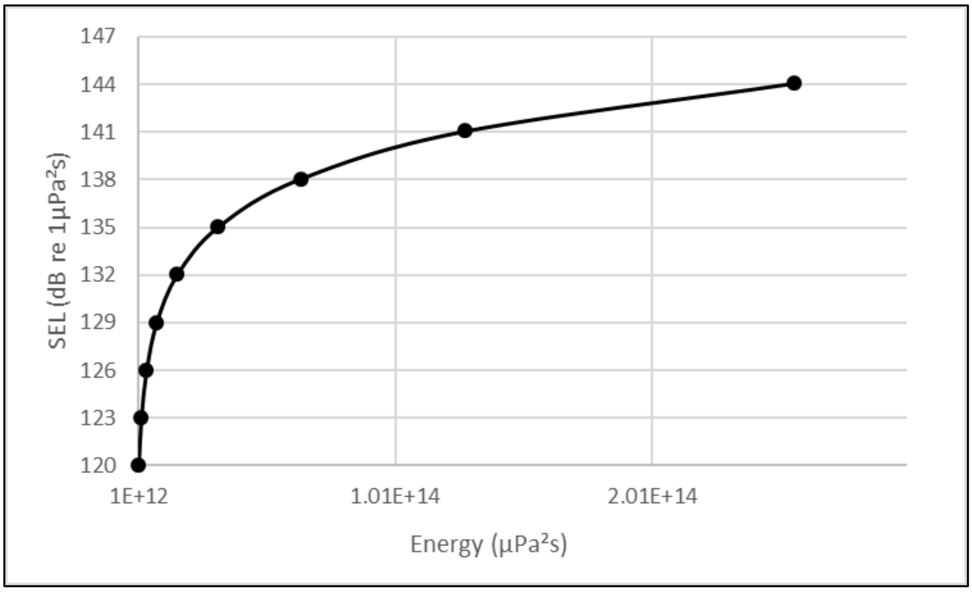


**Figure A 3: Relationship between Energy and SEL. Each successive dot on the black line indicates a doubling of energy and an increase in SEL of 3 dB.**

4.17.1.9 The exposure at which PTS may occur is likely to lie between the impulsive PTS threshold and the non-impulsive threshold, and its value needs to be determined on a case-by-case basis. The resulting "mixed threshold" is not only influenced by the ratio between impulsive and non-impulsive sounds, but also and especially on the characteristics and energy of the first sounds an animal is exposed to (as explained above). As the sound characteristics are expressed in a range dependent probability function, the mixed threshold can be determined with a modelling exercise combined with the safe distance analysis.

4.17.1.10 SMRU Consulting are currently developing methods for such an approach and it is anticipated that such an approach will inform the assessment presented in the Hornsea Four Environmental Statement and will likely incorporate the analysis of additional piling noise data to increase the robustness of such an approach.

4.17.1.11 Nevertheless, the data presented in Hastie *et al.* (2019) provide a good starting point with which to evaluate the potential consequences of the change in impulsiveness of pile driving sounds with range. Based on the data presented therein, it is clear that the probability of pile strike sounds being characterised as impulsive reduced as range increased. For predicting PTS from $SEL_{cum}$ in the PEIR, adopting a benchmark of 80% probability of strikes being non-impulsive (single strike probability) results in a distance of ~1.8 km based on the Moray Firth and 4.4 km based on The Wash data. Further work is required to fully incorporate these findings into predictions of PTS, therefore the PEIR presents, for illustrative purposes, the results of a PTS assessment based on the assumption of a transition point of between 2 and 5 km.